THE ASTROPHYSICAL JOURNAL, 295:287–304, 1985 August 15

S ANDROMEDAE 1885: A CENTENNIAL REVIEW

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Received 1985 January 14; accepted 1985 February 19

ABSTRACT

A definitive light curve of the supernova of 1885 (S And) in M31, based on a new reduction of 40 comparison stars to the V system, and some recently recovered observations, is presented. The prediscovery observations are reexamined, the color and spectral observations are reviewed. The evidence for and against classification as a Type I supernova is discussed. Absolute and differential coordinates are given for the M31 nucleus, the supernova, and a nearby field star.

Detailed analysis of over 500 magnitude estimates, 200 color estimates, 40 spectral observations, 67 transits, and 136 micrometric measurements by some 120 observers leads to the following conclusions: (1) The mean visual light curve is well represented from the end of 1885 August to the beginning of 1886 March by $V = 5.85 + 1.65[\log (t - t_0)]^2$, where the time of maximum is $t_0 = \text{JD } 2{,}409{,}775.0 \pm 1.0 = 1885$ August 21–22. (2) The unusually fast initial decay of 2 mag in 12.5 days (matched only by SN 1939b) is one of the two fastest on record. (3) The well-determined color at maximum and in the next two to three weeks, corresponding to $B-V = +1.31 \pm 0.06$, cannot be due mainly to external reddening in M31 or the Galaxy; declining rapidly after September 10, the color index settled down to $+0.6$ toward the end of October. (4) Except for the unusual color near maximum, the color-luminosity evolution matches that of typical Type I supernovae, if a color excess of $+0.3$ and total extinction of 1.0 V mag is assumed. (5) With this extinction, the absolute magnitude at maximum was $M_0(V) = -19.2$, with $(B-V)_0 = +1.0$, if the corrected distance modulus of M31 is $\mu_0 = 24.07$. (6) The spectral observations, although marginal, are in surprisingly good agreement and show that most emission maxima can be identified with the main lines of typical Type I supernovae within measuring errors and cosmic dispersion. The λ6150 absorption feature was not seen, however, as was the case for some recent supernovae. (7) After 100 yr of free expansion at a typical velocity of 10^4 km s^{-1}, the gaseous remnant should have a radius of 0″.32, and its center should have moved less than 0″.01–0″.02 from its place of origin which, as nearly as can be determined from a provisional reduction of all available transit and micrometer measurements, was located 15″.9 ± 0″.1 in p.a. 255°.6 ± 0°.2 (equinox 1885.75) from the nucleus of M31. The corresponding 1950 coordinates in the FK3 system are $00^h39^m58^s.84$, $+40°59'38''.5$. (8) The nondetection of the optical, radio, and X-ray remnants suggests a low gas density near the object.

Subject headings: galaxies: individual — stars: individual — stars: supernovae

I. INTRODUCTION

One hundred years ago this month the first—and to this day still the brightest—recorded extragalactic supernova appeared near the center of the Andromeda nebula. The unexpected event caused almost as much surprise and wonder among astronomers as had Tycho's nova three centuries earlier. It reactivated the long debate on the nature of the "white nebulae," whether external galaxies or not. Curiously, the very brilliancy of S And was used as an argument against the concept of "island universes," mainly because the extraordinary absolute luminosity implied seemed too far in excess of that of the Sun and other stars to be plausible.

Although there have been a number of previous review papers on the history and light curve of S And (Hartwig 1920; Lundmark 1920; Parenago 1949; Nielsen 1958; Gaposchkin 1961; Glyn Jones 1976), its classification as a probable Type I is still in doubt, particularly because of its unusually fast decay, its pronounced orange color at maximum, and indefinite spectral features (Payne-Gaposchkin 1936; Minkowski 1939). Because of the current renewal of interest in the theory and observation of supernovae, and their possible use as extragalactic distance indicators, this seems to be an appropriate time for a new evaluation of all available data on S And based on modern values for the comparison stars and previously unused observations (de Vaucouleurs and Buta 1981; de Vaucouleurs, Hansson and Lyngå 1985).

In the following sections we will reexamine the critical prediscovery and early observations of S And (§ II), discuss the magnitude scales and comparison stars (§ III), derive a substantially definitive light curve in the V system (§ IV), and discuss the color (§ V) and spectral information (§ VI). Next, we consider the evidence for and against the classification of S And as a Type I supernova and review the unsuccessful attempts to detect the optical, radio, and X-ray emission from the remnant (§ VII). Finally, to assist the search for this remnant, we derive precise absolute and differential coordinates for S And, the nucleus of M31, and a nearby field star with negligible proper motion.

II. PREDISCOVERY AND EARLY OBSERVATIONS

The new star was discovered on 1885 August 20 by E. Hartwig at Dorpat, but bad weather and administrative prudence conspired to delay until August 31 the telegraphic announcement to the central bureau in Kiel (Hartwig 1885*a*, *b*, *c*, 1920). After the announcement became generally known on September 1–2, a number of independent discoveries, a few earlier than August 20, came to light, and—no less important—a number of negative observations were reported, all of them but one earlier than August 17. The agreement between the statements of Max Wolf (1885) at Heidelberg, Tempel (1885) at Arcetri, and Engelmann (1885*a*) at Leipzig that nothing unusual was visible on August 16 is particularly compelling. The latter observer added that if a star brighter than $m = 8$–9 (Bonner Durchmusterung [Argelander 1886, hereafter BD] scale, corresponding to $V \approx 9$, see § III) had been present in the center of M31 on that day he could not have failed to notice it.

On August 17 and 18 a British amateur, P. H. Silcock at Brixton, using a 90 mm refractor, had not noticed anything unusual in M31 (he saw the star on September 1), but cautioned that he was "but a beginner" (1885). This negative report conflicts with the positive observation of L. Gully, a professor of mathematics and astronomy at Rouen, who on the 17th was surprised to see a bright star in the center of M31 while testing a new 20 cm Foucault reflector (Gully 1885*a*, *b*). As noted by Hartwig (1920), the agreement between the date and the day of the week (a Monday) given by Gully appears to preclude an error or a misprint in his report.[1] Considering their respective telescopic apertures and levels of expertise, the positive observation by Gully and the negative recollection by Silcock may, perhaps, be reconciled if the star was of magnitude 9–8 August 17–18.[2]

The last positive report prior to Hartwig's observation was by an Irish amateur, I. W. Ward, at Belfast, who claimed to have seen the star at $m \approx 9.5$ on August 19, presumably with his 11 cm refractor (Ward 1885*a*, *b*). This observation is difficult to reconcile both with the Gully report on August 17 and Hartwig's observation of August 20 when he judged the star to be of magnitude 6–6.5 if not brighter (in retrospect he later made it brighter, perhaps $m \approx 6$).[3]

After August 20 all reports are uniformly positive (Table 1) and confirm Hartwig's observations. The star was seen on August 22 in Hungary (no magnitude given; Konkoly 1885*a*, *b*, 1887); on August 25 Max Wolf saw it at an estimated magnitude of $m \approx 6$.[4] On August 27 Hartwig (1885*b*, *c*), observing between clouds with an 83 mm refractor, initially estimated it to be about $m \approx 7$ (but later revised it to "noch heller als 7m," although it was already "viel schwächer als an Entdeckungstage"); on August 29 he was finally able to obtain actual comparisons with nearby stars and judged it to be two to three steps fainter than DM $+39°158$ ($m = 7.0$ on the BD scale) and about equal to DM $+39°167$ ($m = 7.1$); these stars have modern magnitudes of $V = 7.01$ and 7.20 respectively, and at these magnitudes Hartwig's step value was 0.07 mag (Zinner 1932), so that S And must have been at $V = 7.2$ (on the same night it was also observed in the US and in Norway, but no magnitude estimates were reported).

On August 30 several independent discoveries were made by amateurs in France, Germany, and the US (Table 1), who variously estimated the magnitude as ~ 5.7 (von Spiessen), ~ 6 or slightly fainter (Thibault), 6–7 (Pavey), and 6.5–7 (Moore). Finally, on August 31, E. Lamp at Kiel Observatory, checking Hartwig's telegraphic message, judged the star to be at $m = 7.4$ by comparison with DM $+39°158$. Independent estimates on the same night ranged all the way from 5–6 (Oppenheim) to 6.5–7 (Moore: "same as Aug 30") and 7.5 (Hartwig: "4 stufen schwächer als am 29. August"). The disagreement between the Kiel and Dorpat observations of August 29 and 31 ($V = 7.2$ and 7.4–7.5) on the one hand and the amateur reports of August 30 and 31 ($m \approx 5.7$–6.7) on the other is attributable to the low powers used in the latter observations.[5]

The trend of the much better determined light curve after September 1 (§ IV) confirms this interpretation.

III. OBSERVERS AND COMPARISON STARS

a) *Observers and Methods*

Table 2 presents a summary of the sources of photometric data on S And. These observations may be divided into four groups:

A. Actual photometric measurements, either with a Zöllner photometer (Charlier at Uppsala, Müller at Potsdam) or with a wedge photometer (Pritchard at Oxford, Young and McNeill at Princeton), and for which the adopted magnitudes of the standard stars are specified or can be determined;

B. Comparisons by the step method and for which the step estimates were published in detail. These can be reduced anew to the V system, once the comparison stars have been identified and remeasured. The most valuable sets in this class are those of Bigourdan at Paris Observatory, whose long-forgotten observations have been previously reduced to the V system (de Vaucouleurs and Buta 1981), and of Dunér at Lund Observatory, recently retrieved from the archives of that observatory (de Vaucouleurs, Hansson, and Lyngå 1985).

C. Magnitudes derived by interpolation between specified comparison stars, or on an identified magnitude scale (generally the BD), but for which details of the individual step estimates were not published. Such observations can be

[1] Another possibility, suggested by Nielsen (1958, 1961), is that the date reported in Gully's letter might be in error, and that his observation was actually made on the following Monday, August 24; there is one difficulty with this suggestion: Gully explains that "Le soir de ce jour, en effet, je montrais les différentes constellations au public ..." (1885*a*, *b*), which would have been possible on the 17th (when the Moon was at its first quarter), but difficult or impossible on the 24th (when the Moon was almost full). Likewise it would have been most unusual to choose the night of the full Moon to show the Andromeda nebula to visitors.

[2] A modern review (Glyn Jones 1976) states that Gully "estimated the object to be between 5 and 6 magnitudes," but the reference given (Flammarion 1885) is silent on this point, and no magnitude estimate is mentioned in Gully's letter, the full text of which was reproduced in both *Ciel et Terre* (1885 Oct 1) and *Astronomische Nachrichten* (No. 2691). This appears to be a repetition of an interpretation of Gully's qualitative observation by Gaposchkin (1961) as "adopted magnitude 5–6."

[3] It may be noted that a year later Ward (1886) was among the few observers who reported a new brightening of the center of M31 which could not be confirmed by others with much larger telescopes (Copeland 1886; Tarrant 1886). The reliability of Ward's ill-documented claim has already been questioned by Gaposchkin (1961). It also conflicts with a report of two French amateurs, M. Codde and B. Lihou, who had observed a 7th magnitude star in the center of M31 with a 75 mm refractor at Marseilles (Flammarion 1885), probably on August 19 (possiibly 18 or 20), since the date given (August 10, the day of the new Moon) is contradicted by their specific description of the strength of the moonlight and is probably a misprint (de Vaucouleurs 1985*b*).

[4] Gaposchkin (1961), and, after him, Glyn Jones (1976) interpret this to mean $m \approx 6.5$–7 on a modern magnitude scale; comparison of the values assigned to 6th magnitude stars in Andromeda on the BD scale and in the V system (§ III*c*) does not support this interpretation.

[5] Several observers commented on the fact that the star was estimated fainter by several tenths of a magnitude when observed through larger telescopes or with higher magnifications (e.g., Engelmann 1885*a*, *b*; Copeland 1886; Backhouse 1888). It is clear that at low magnifications the apparent magnitude of the star was enhanced by the integrated luminosity of the bright central part of the nebula. This also explains why several reliable observers reported seeing the star with the naked eye (e.g., Brooks and von Spiessen on September 2, Krueger and von Gothard on September 5, Denning on September 8, and Peek on September 11) when its true magnitude was only 7.7–8.7.

TABLE 1

PREDISCOVERY AND EARLY OBSERVATIONS

Date (1885)	Observer	Telescope Type, Aperture[a]	Star?	m	V	Notes
Aug 1–15....	several	r, 7.5–25; R, 15	no	...	...	
Aug 16	M. Wolf	r, 15	no	...	...	
Aug 16	Engelmann	r, 20	no	...	...	
Aug 16	Tempel	r, 24	no	>8–9	>9	
Aug 17	Silcock	r, 9	no	...	...	
Aug 17	Gully	R, 20	yes	...	(8–9)?	
Aug 18	Silcock	r, 9	no	...	...	
Aug 19	Lihou	r, 7.5	yes	7	(7–8)?	b
Aug 19	Ward	r, 11	yes	9.5	?	c
Aug 20	Hartwig	r, 23	yes	6–6.5	5.8–6.5	d
Aug 22	Podmanicky	r, 9	yes	...	...	
Aug 25	M. Wolf	r, 15	yes	6	5.8?	e
Aug 27	M. Wolf	r, 15	yes	...	...	
Aug 27	Hartwig	r, 8.3	yes	<7	6.8	f
Aug 29	McClure	?	yes	...	...	
Aug 29	Olsen	r, 35	yes	...	...	
Aug 29	Hartwig	r, 23	yes	7.1	7.2	g
Aug 30	several	r, 7.5–10	yes	5.7–6.7	?	h
Aug 31	several	r, 9–23	yes	5.5–7.4	7.4	i

[a] r = refractor, R = reflector; aperture in cm; references in Table 2.

[b] Date uncertain (see text).

[c] Magnitude and/or date uncertain (see text).

[d] Hartwig's early reports (1885*b*) gave only "mindestens die siebente Grösse"; a much later recollection (1920) was "wenigstens noch uber der Grösse 6.5 gelegen, vielleicht 6m gewesen sein" or "etwa die sechste Grösse"; later still, Zinner (1932) quotes only $m = 6$.

[e] It is not clear whether "6" means between 5.5 and 6.5 or, perhaps, 6.0 to 6.9 ("of the sixth class"); full Moon.

[f] Hartwig's early report (1885*c*) had "etwa 7. Grösse," later (1920) "noch heller als 7*m*."

[g] First magnitude from actual step estimates "a 2–3 S = b," where a = DM +39°158 (7.0) = No. 2 ($V = 7.01$); b = DM +39°167 (7.1) = No. 27 ($V = 7.20$).

[h] Independent discoveries by Moore (Texas, r, 10, $m \approx 6.5$–7); Pavey (Ohio, *r*, ?, $m \approx 6$–7); Lajoye (France, r, ?, no mag); Thibault (France, r, 7.5, $m \approx 6$–6.5 "de 6e grandeur, mais un peu plus terne"); von Spiessen (Germany, r, 9, $m \approx 6$ "etwa gleich π Aql" [$V = 5.7$]). Most early estimates by amateurs using small telescopes and/or low magnifications are systematically too bright (see text).

[i] Moore (same as Aug 30); Oppenheim (Berlin, r, 9, $m \approx 5$–6); E. Lamp (Kiel, r, 20, $m \approx 7.4$, by comparison with DM +39°158 (7.0); Hartwig: "4 Stufen (etwa 0.2–0.3 Gr. kl.) schwächer ... als am 29 Aug."

reduced to the V scale only statistically via a mean relation between the observer's adopted magnitudes of the comparison stars and their recently measured V magnitudes. In this class are the largest sets of observations, including those of Hartwig, reduced by Zinner (1932); of the Radcliffe observers (Stone 1885); of Engelmann (1885*a*, *b*) at Leipzig; of Parkhurst (1886*a*, see also 1886*b*) in Brooklyn; and a few shorter ones.

D. Finally, some observers published magnitude estimates without identifying their comparison stars or their magnitude scales. These are the least useful, although some fairly large sets, e.g., by Espin (1886), Trouvelot (1885), and by the Baxendells, father and son (1886) can be reduced *a posteriori* to the mean V system defined by a preliminary mean light curve of S And. Unfortunately, the 10 most important early observations in 1885 August (Table 1), and the dozen or so at the end in 1886 January–March, are also in this class. However, fairly precise magnitudes can be inferred from the dates when the star was last seen with telescopes of various apertures and magnifications (de Vaucouleurs 1985*b*).

Altogether, over 500 magnitude records by some 80 observers (Table 2) are available to reconstruct the light curve from 1885 August 17 to 1886 March 6.

b) Comparison Stars

The comparison stars used by the main observers are listed in Table 3 and marked in Figures 1 and 2 (Plate 11). The corresponding zone numbers in the Bonner Durchmusterung (DM) and approximate 1950 coordinates in the AGK3 system (Heckmann *et al.* 1975) are also given.

The magnitudes and colors of these stars were measured in the *UBV* system with the 76, 91, and 205 cm reflectors of McDonald Observatory. In addition to two stars (Nos. 3, 15) observed by Arp (1956) and to five stars (Nos. 1, 3, 9, 10, 29) observed in 1980 November (de Vaucouleurs and Buta 1981), all stars were observed at least once (by H. G. C.) in 1982 October and November and 1983 October; a few were also measured (by G. de V.) in 1982 November (Nos. 1, 3, 4, 5, 9, 10, 38). Intercomparison of 22 duplicate measurements of 10 stars indicates that the external mean errors are 0.020 mag for the V magnitudes, 0.015 for $B-V$, and 0.017 for $U-B$ for single observations. The adopted mean magnitudes and colors are collected in Table 3, where n is the number of observations. The BD identifications (DM) and magnitudes (m) are also given.

c) The BD Scale

Because the magnitude scale of the Bonner Durchmusterung was in very frequent use in the 1880s, many observations of S And were *de facto* on the BD scale, even when it was not explicitely designated by the observer. It is, therefore, important to establish the relationships between this scale and the V system, particularly in the region of Andromeda. These were derived from a sample of BD magnitudes, including the Bayer-Flamsteed stars ($m < 6.5$) of the constellation, some 6th to 8th

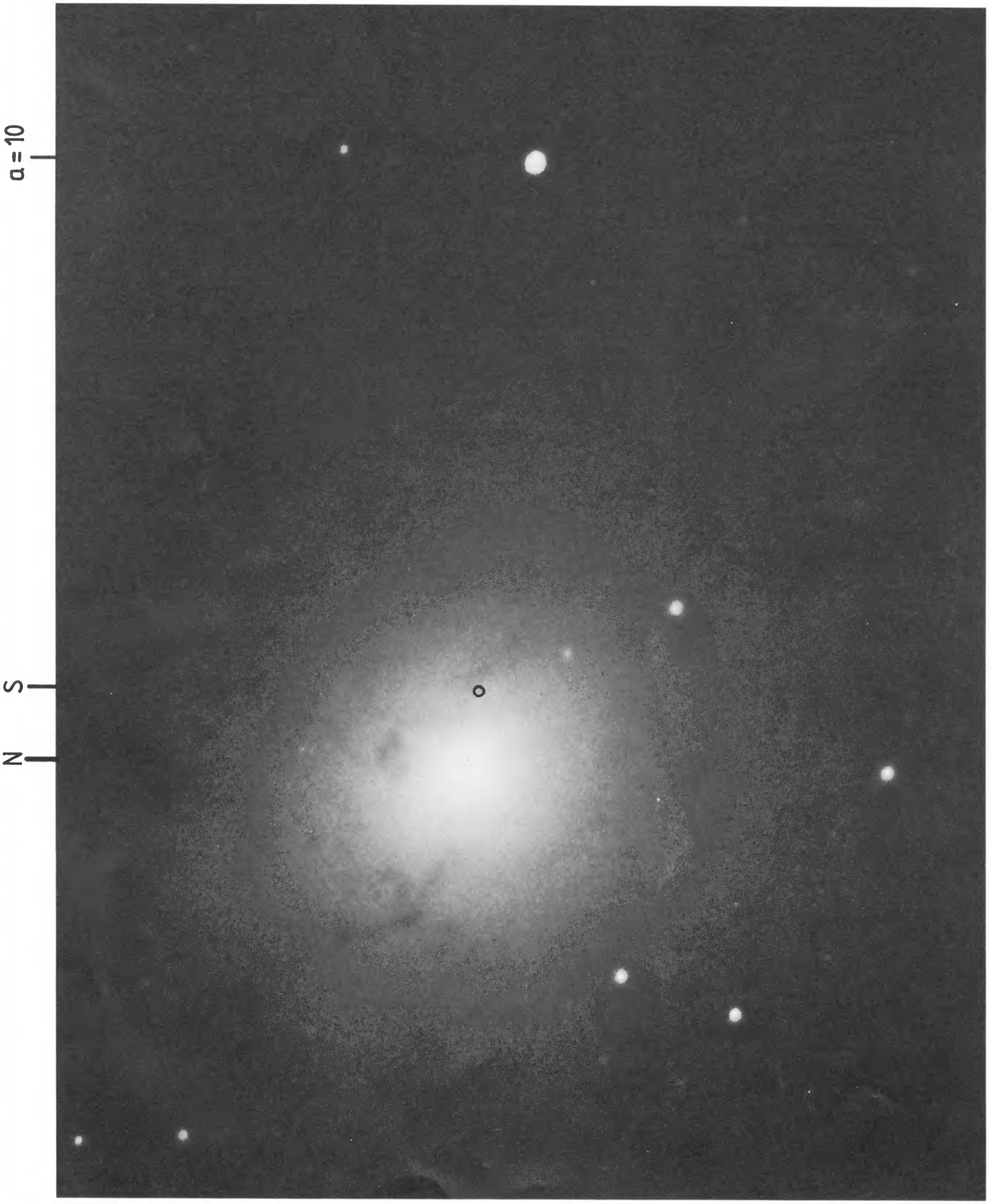

FIG. 2.—Photograph of center of M31 showing location of S And

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TABLE 2A

S Andromedae: Sources of Magnitudes and Photometry

(Number of Reported Observations)

Name	Telescope	A	B	C	D	Reference
Allen	r.66		1			AmJS 31,299
Backhouse	r.11			5		MN 48,108
Bakhuyzen	r.27			5		AN 2683,323
Barnard	r.15		1		1	SM 4,241
Baxendell	r.15				14	Obs 9,94
Baxendell, jr	r.15				10	Obs 9,94
Bellamy	r.18,t.12			13	3	MN 46,56
Bigourdan	r.30		13			PASP 93,294;BA 2,452
Brooks	R.23				1	SM 4,246
Charlier	r.16	4				AN 2687,389;2698,165
Common	r.15		2			Nat 32,522
Copeland	r.15,r.38			22	3	MN 47,49
Cortie	r.20		4		2	MN 46,22; unpubl.
Cruls	r.23		3		8	CR 102,405
Davis	r. 9				1	JLAS 4,6
Denning	R.25				1	Nat 32,465
Duner	r.24		10			PASP ...
Eastman	t.15				2	USNO 1885,82
Engelhardt	r.30		5		7	AN 2681,285;OAE 1886,53
Engelmann	r.20			22	2	AN 2683,323;2704,269
Espin	R.43				11	Obs 9,156
Flammarion	r.11		2		2	L'A 4,362
Folie	r.38		1		1	AN 2678,248
Gemmill	r. 8				1	EM 1071,104
Gothard	R.27				2	AN 2687,390
Hagen	r.11		12			SM 4,285;OVS 1891,78
Hall, A.	r.66				9	AmJS 31,299
Hall, M.	r.10		3			Obs 9,69
Hartwig	r.23		5	22	2	AN 2678,245;2681,285; 2685,355;VBS I,Nr3
Holmes	r.23				2	EM 1069,57;1072,120
Huggins	r.38				1	Obs 8,333;Nat 32,465
Hunt	r.20				1*	EM 1089,468
Ingall	r.25				1	EM 1068,81
Kammermann	r.28?		1		2	AN 2682,299;2687,387
Klein	r.15				3	WA 28,292,335,351
Knobel	R.21				3	Kno 202,222;203,239
Krueger	r.20				1	BVS 217
Kustner	t.19				8	AN 2756,335
Lamp, E.	r.20		1		2	AN 2678,245
Lamp, J.	r.29				6	AN 2690,21
Laschober	r.15				1	AN 2726,213
Lihou	r. 7				1	L'A 4,364
Lohse	r.39			4		MN 466,299

Name	Telescope	A	B	C	D	References
Maunder	r.32				4	MN 46,19
McNeill	r.58	11				unpublished
Middleton	r. 6				1	EM 1068,31
Millosevich	r.39?				2	AN 2683,321;AMI 1885,77
Moore	r.10				2	AN 2688,403;SM 4,242
Muller	r.13, r.20	13				AN 2690,23
Numsen	r.10		26			SM 4,278,301;EM 1073,138
Oppenheim	r. 9				1	AN 2678,245
Parkhurst	r.23			40		SM 5,90;HA 29,94,141
Paul	t.15				2	Sci 6,310;USNO 1885,82
Pavey	r.?				1	SM 4,287
Peek	r.16		1	16		EM 1068,32;RO 1886,18
Perry	r.20				1	MN 46,22
Porter	r.28				4	SM 4,316
Pritchard	r.31?	17				MN 46,18
Pritchett	r.31				1	Obs 9,233
Ricco	r.25				1	AN 2682,300;Nat 32,523
Robinson	r.18, h.19			8		MN 46,56
Schrader	r.25				1	AN 2678,246
Spiessen	r. 9				1	AN 2681,283
Spitaler	t.11				1	AN 2681,284
Tarrant	r. 7, R.26				2	EM 1074,32,158; Kno 203,238
Tempel	r.24				1	AN 2682,301
Thibault	r. 7				1	BA 2,451;L'A 4,363;
Trouvelot	r.20				9	CR 101,799;L'A 4,403
Tupman	R.47				2	Kno 203,238
Valentiner	t.?				1	AN 2688,403
Vogel	r.30		3			AN 2687,387
Ward	r.10				4	AR 23,242;EM 1073,138
Whitley	r.?				1	Obs 8,333
Wickham	r.18, h.19			10	3	MN 46,56
Wilson	r.28				4	SM 4,316
Winlock	t.15		1		6	USNO 1885,82;Sci 6,310
Wolf, M.	r.15				1	AN 2681,284
Wolfer	r. 8		15			AMitt 65,206
Woodside	r. 6, R.16				1	EM 1077,221
Young	r.58	9			3	SM 4,282; unpubl.
Totals		54	110	167	177	508

* Last observation (no magnitude).

TABLE 2B

KEY TO JOURNAL ABBREVIATIONS

AMI	*Annali della Meteorologia Italiana* (Rome)
AMitt	*Astronomische Mittheilungen* (R. Wolf, Zürich)
AmJS	*American Journal of Science*
AN	*Astronomische Nachrichten* (Kiel)
AR	*Astronomical Register*
BA	*Bulletin astronomique* (Paris)
BVS	*Beobachtungen Veränderlicher Sterne* (J. G. Hagen, Berlin, 1903)
CR	*Comptes-Rendus de l'Académie des Sciences* (Paris)
EM	*English Mechanic* (London)
HA	*Annals of the Harvard College Observatory*
JLAS	*Journal of the Liverpool Astronomical Society*
Kno	*Knowledge* (London)
L'A	*L'Astronomie* (C. Flammarion, Paris)
MN	*Monthly Notices of the Royal Astronomical Society*
Nat	*Nature* (London)
OAE	*Observations astronomiques* (d'Engelhardt, Dresden)
Obs	*The Observatory*
O'GB	*O'Gyalla Beobachtungen* (N. von Konkoly, 1887)
OVS	*Observations of Variable Stars* (J. G. Hagen, Georgetown College Observatory, Washington)
PASP	*Publications of the Astronomical Society of the Pacific*
RO	*Rousdon Observatory Publications* (C. E. Peek, 1886)
Sci	*Science* (New York)
SM	*The Sidereal Messenger* (Northfield, Minn.)
USNO	*US Naval Observatory, Observations 1885* (Washington, 1891)
VBS	*Veröffentlichungen der Remeis-Sternwarte* (Bamberg, Zinner 1932)
WA	*Wochenschrift für Astronomie* (H. J. Klein, Halle, 1885)

magnitude stars within 10° of M31, and those of Table 3 ($m > 6.5$). It is clear that the naked-eye stars and the telescopic stars form two distinct systems which do not match well near $m \approx 6.5$. This complicates the interpretation of the magnitude estimates near the time of the maximum of S And which was reported by most observers as close to "6th magnitude." The following approximate linear transformation equations may be adopted:

$$V - 4 = 0.87(m - 4) \quad \text{for } 3.2 \leq m \leq 6.2 \,, \tag{1}$$

$$V - 7 = 1.20(m - 7) \quad \text{for } 6.2 \leq m \leq 9.5 \,. \tag{2}$$

In both cases the dispersion (after rejection of two aberrant residuals in each case) is $\sigma = 0.23$ mag, in good agreement with the known mean error of the BD scale, $\sigma = 0.24$ mag (Zinner 1926). For $m = 6.0$ (BD scale), these equations predict $V = 5.74$ and 5.80 respectively. The mean V magnitude of the 12 stars having $m = 6.0$ in the sample is $\langle V \rangle = 5.77 \pm 0.09$, with a standard deviation of 0.30.

IV. THE MEAN LIGHT CURVE

a) Reduction to the V System

Observations in groups A and B were directly reduced to the V system by means of the known V magnitudes of the comparison stars (Table 3). No attempt was made to correct for color equation because the number of comparison stars is usually too small to detect its effects, and the colors of most comparison stars were similar to that of S And (§ V).

Magnitude values in group C that were reported to be "on the BD scale" were reduced to the V system via equation (2); for the others, the given magnitudes of the comparison stars were compared to the V magnitudes of Table 3 and transformed to the V system by a linear or graphical fit to (V, m)-plots or, in some cases, just a constant mean zero-point shift.

Apart from differences in zero point and magnitude scale, photometric observations can also differ because of systematic errors and personal equation. Two particularly severe systematic errors were noted in several sets of observations:

1. in some sets (e.g., Pritchard, Hagen) the magnitude of S And seemed to become constant after a few weeks. This is obviously due to contamination by the bright nuclear region which became dominant as the star became fainter. This error is particularly clear in Pritchard's measurements made by the extinction method with his wedge photometer (Pritchard 1885). Consequently, all his magnitude values after September 21 were rejected.

2. in several sets (A. Hall, Numsen, Parkhurst), an opposite effect appeared at a fainter magnitude level during the later phases of the decline, particularly when S And became fainter than the 11th–12th magnitude central nucleus only 16″ away. Then the star was often estimated too faint and appeared to drop rapidly before fading completely out of sight. This effect has greatly distorted the later part of the light curve in previous studies.

In addition to identifiable sources of systematic errors, personal equation is in evidence in many sets due to such causes as color equation, position angle equation, method of observation, instrumental and magnification effects, etc., which were not yet known to most observers in those early days of stellar photometry.

In order to minimize these various sources of error the reduction proceeded in three steps:

i) A preliminary reduction to the V system was made for all observations in groups A, B, and C and a provisional mean light curve derived; residuals from it were tabulated for each observation in each set.

ii) Observations subject to the effect of low magnification (e.g., Backhouse, Copeland) or of bright background toward the end (e.g., A. Hall, Parkhurst) were corrected according to simple error models (de Vaucouleurs 1985*b*).

iii) Observations which, apart from these effects, seemed to be affected by a large and reasonably constant personal equation relative to the provisional mean curve (e.g., the Parkhurst

TABLE 3

COMPARISON STARS FOR S ANDROMEDAE

NUMBER	R.A. (1950) (00^h+)	Decl. (1950)	DM	m(BD)	V	B−V	U−B	n	NOTES
1.........	$38^m46^s.1$	41°05′45″	40°143	9.5	9.96	1.33	+1.44	5	
2.........	39 17.6	40 24 54	39.158	7.0	7.01	0.47	−0.05	1	
3.........	39 25.2	41 07 05	40.144	9.5	10.35	1.14	+1.04	5	
4.........	39 28.0	40 51 52	...	...	12.14	0.25	+0.16	3	
5.........	39 40.0	40 58 30	...	...	14.02	0.60	+0.08	2	a
6.........	39 42.1	40 49 22	...	...	10.47	1.61	+1.98	1	
7.........	39 46.4	40 40 49	40.145	9.0	9.28	0.71	+0.26	1	
8.........	39 46.9	40 53 45	...	...	11.14	0.35	+0.07	1	
9.........	39 49.2	41 06 43	...	...	11.13	1.03	+0.73	5	
10.........	39 49.4	40 59 24	...	...	12.32	0.57	+0.09	4	b
11.........	39 53.4	41 25 34	40.146	8.8	9.44	1.03	+0.82	1	
12.........	40 06.3	40 56 09	...	...	12.22	0.59	+0.03	1	
13.........	40 21	41 08	...	...	12.72	0.74	+0.30	1	c
14.........	40 29.8	40 44 08	40.149	9.1	9.20	0.99	+0.72	3	
15.........	40 30.0	41 08 36	...	...	11.98	0.54	−0.01	2	d
16.........	40 31.5	41 00 07	...	...	12.26	0.48	+0.03	1	
17.........	40 36.9	41 05 32	...	...	11.14	0.99	+0.62	1	
18.........	40 40.9	41 07 30	...	...	12.11	0.60	+0.07	1	d
19.........	40 53.8	40 37 50	40.150	9.5	10.25	1.02	+0.89	1	
20.........	40 54.5	41 06 09	...	...	10.62	0.50	+0.04	1	
21.........	41 19.2	41 17 50	40.151	8.9	9.03	1.05	+0.92	1	
22.........	41 20.7	40 09 38	39.165	8.0	8.39	1.13	+1.06	1	
23.........	41 24.6	41 03 49	...	...	11.14	0.50	+0.02	1	
24.........	41 32.3	40 24 42	39.166	8.5	8.61	1.55	+1.97	1	
25.........	41 45.6	40 59 16	...	...	11.17	0.45	−0.05	1	
26.........	41 48.4	41 01 25	...	...	12.25	0.48	−0.02	1	
27.........	41 52.7	40 24 22	39.167	7.1	7.20	1.61	+1.65	1	
28.........	41 56.0	41 02 45	...	...	11.23	0.58	+0.05	1	
29.........	42 02.6	41 02 24	40.154	9.0	9.13	1.00	+0.74	5	
30.........	42 55.6	40 55 01	40.156	9.0	8.99	1.06	+0.86	1	
31.........	43 18.0	40 32 11	40.158	7.5	7.54	0.48	−0.02	1	
32.........	43 19.6	41 15 49	40.157	9.1	9.70	1.46	+1.69	1	
33.........	43 21.8	41 02 09	40.159	9.5	10.26	0.48	+0.05	1	
34.........	44 34.9	41 01 34	40.161	9.1	9.18	1.68	+2.04	1	
35.........	44 57.3	41 00 52	40.162	9.1	9.42	1.60	+1.93	1	
36.........	45 32.8	41 19 27	40.163	9.0	9.20	1.57	+1.93	1	
37.........	46 16.4	40 51 35	40.165	7.9	7.59	1.15	+1.08	1	
38.........	46 30.4	40 48 35	40.167	7.7	7.04	1.03	+0.84	2	
39.........	41 05.6	41 07 47	...	...	11.46	0.46	+0.03	1	
40.........	34 51.0	41 08 38	40.127	8.2	8.64	1.33	+1.60	1	
41.........	35 07.8	40 35 48	40.128	8.1	8.45	1.15	+0.99	1	
42.........	38 14.0	41 27 24	40.142	8.8	9.32	0.40	+0.07	1	

[a] Coordinates precessed from Copeland 1886.
[b] 12th magnitude star 2′ west of S And = "D'Arrest's star" = Barnard's reference star *a* (Barnard 1898).
[c] Supplementary star, approximate coordinates.
[d] Supplementary star.

set prior to October 23) were corrected accordingly, and a revised mean light curve was established, individual observations being weighted according to the indications given by the original observer (clouds, haze, seeing, etc.) and the degree of consistency with observations immediately preceding or following. The best series in this respect are those of Copeland, Dunér, Engelmann, Hagen, Hartwig, and Wolfer, and those from the Radcliffe observers. Curiously, the few sets based on actual photometric measurements (Group A) were not among the most accurate, although in the mean they agree well enough with those based on interpolations (Groups B and C).

Finally, the longer series from Group D (e.g., Espin, Trouvelot, and the Baxendells) were reduced to the system defined by the mean light curve to help fill in gaps or increase the weight of the daily means without changing the system. Isolated observations in this group were not used, except in the early and late phases where there is no alternative. These were analyzed individually in great detail in an attempt to correctly interpret the "magnitudes" reported by each observer. Details of these reductions will be reported elsewhere (de Vaucouleurs 1985*b*).

b) The Mean Light Curve

Rather than recount the tedious successive approximations leading to the adopted mean light curve, we will compare the individual observations to the formula which gives a smooth fit to the mean points:

$$[V] = 5.85 + 1.65[\log (t - t_0)]^2 , \quad (3)$$

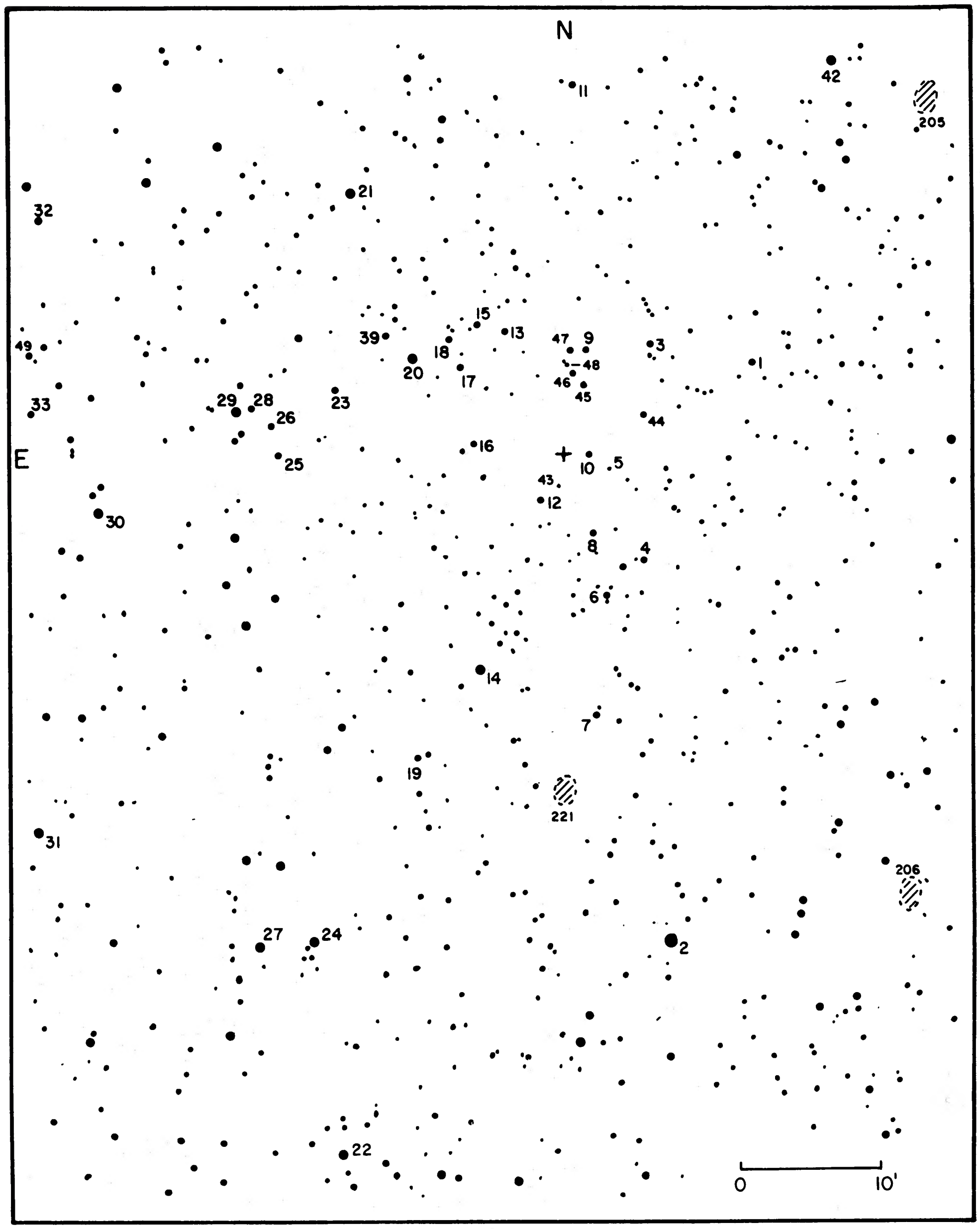

FIG. 1.—Chart of comparison stars of S And. Plus marks center of M31. Stars 43–49 were used for astrometric comparisons only.

where the time of maximum is $t_0 = \text{JD}$ 2,409,775.0 $\pm$ 1.0 = 1885 August 21–22. A comparison of the provisional mean points resulting from the first approximation (Table 4) with the calculated values (Fig. 3) shows that the formula represents the data within their errors for the whole interval of time covered by the observations from 1885 late August to 1886 March. The corresponding rate of decay decreased from 0.165 mag day^{-1} during the first 10 days to $\sim$0.02 mag day^{-1} toward the end (after 150 days past maximum) when it approximated the typical exponential decay of the light curves of Type I supernovae (Barbon, Ciatti, and Rosino 1973, hereafter BCR). The initial decline of S And was extremely fast, however, amounting to $\sim$1 mag in the first 6 days, 2 mag in 12.5 days, and 3 mag in 22.5 days. At the time several observers reported apparent halts or even fluctuations on the descending branch of the light curve, but comparisons of the results of different observers show little or no agreement on the times and levels of such supposed halts, which we are inclined to attribute to the small discontinuities introduced in the magnitude estimates by changes of observing conditions and, particularly, of comparison stars.

The validity of equation (3) can be checked in three ways:

i) *Comparison with the observed provisional mean points.*—As shown by Figure 3, no significant systematic departure is in evidence. Small fluctuations are attributable to changes in the observer and comparison star mix.

ii) *Magnitudes based on observations of equality with comparison stars.*—Among the most reliable observations are those of equality of apparent magnitudes of S And and a nearby comparison star, which avoids the additional uncertainty of interpolation or extrapolation. A list of 39 such observations is given in Table 5. A plot (Fig. 4) of the residuals $[V] - V$

TABLE 4

MAGNITUDES OF S ANDROMEDAE REDUCED TO V SYSTEM

Date 1885		$t-t_0$ days	[V]	$\langle V\rangle$	n	$[V]-\langle V\rangle$ x100	$\langle V_c\rangle$	n_c	$[V]-\langle V_c\rangle$ x100
Aug	29	8	7.20	7.20	1	0	7.15	1	+ 5
	31	10	7.50	7.40	2	+10	7.38	2	+12
Sept	1	11	7.64	7.66	3	- 2	7.71	5	- 7
	2	12	7.77	7.78	5	- 1	7.71	6	+ 6
	3	13	7.90	7.89	7	+ 1	7.89	10	+ 1
	4	14	8.02	8.10	1	- 8	7.98	2	+ 4
	5	15	8.13	8.08	4	+ 5	8.16	7	- 3
	6	16	8.24	8.25	4	+ 1	8.24	8	+ 1
	7	17	8.35	8.15	1	+20	8.22	5	+13
	8	18	8.45	8.57	3	-12	8.48	5	- 3
	9	19	8.55	8.74	8	-19	8.52	10	+ 3
	10	20	8.64	8.67	3	- 3	8.62	4	+ 2
	11	21	8.73	8.88	4	-15	8.79	6	- 6
	12	22	8.82	9.13	11	-31	8.87	14	- 5
	13	23	8.91	8.96	5	- 5	8.95	8	- 4
	14	24	8.99	9.03	8	- 4	9.05	11	- 6
	15	25	9.07	9.23	10	-16	9.16	11	- 9
	16	26	9.15	9.28	9	-13	9.06	12	+ 9
	17	27	9.23	9.40	12	-17	9.21	13	+ 2
	18	28	9.31	9.31	7	0	9.27	11	+ 4
	19	29	9.38	9.48	8	-10	9.33	9	+ 5
	20	30	9.45	9.22	3	+23	9.48	5	- 3
	21	31	9.52	9.52	7	0	9.55	6	- 3
	22	32	9.59	9.60	8	- 1	9.57	9	+ 2
	23	33	9.65	9.70	2	- 5	9.62	3	+ 3
	24	34	9.72	9.80	4	- 8	9.60	4	+12
	25	35	9.78	9.95	8	-17	9.68	11	+10
	26	36	9.85	10.40	4	-55	9.92	6	- 7
	27	37	9.91	9.95	2	- 4	9.79	5	+14
	28	38	9.97	10.20	3	-23	9.94	5	+ 3
	29	39	10.03	10.38	8	-35	9.92	8	+11
	30	40	10.08	10.32	5	-24	10.08	5	0
Oct	1	41	10.14	10.35	3	-21	10.26	6	-12
	2	42	10.20	10.13	3	+ 7	10.18	5	+ 2
	3	43	10.25	10.79	3	-54	10.35	4	-10
	4	44	10.31	10.75	3	-44	10.41	4	-10
	5	45	10.36	10.54	5	-18	10.35	5	+ 1
	6	46	10.41	10.77	3	-35	10.53	2	-12
	7	47	10.46	10.86	3	-40	10.57	6	-11
	8	48	10.51	10.68	1	-17	10.57	2	- 6
	9	49	10.56	10.79	2	-23	10.53	4	+ 3
	10	50	10.61	10.80	2	-19	10.63	8	- 2
	11	51	10.66	10.66	1	0	10.77	2	-11
	12	52	10.71	10.96	1	-25	10.66	1	+ 5
	13	53	10.76	10.66	3	+10	10.90	3	-14

Date 1885		$t-t_0$ days	[V]	$\langle V\rangle$	n	$[V]-\langle V\rangle$ x100	$\langle V_c\rangle$	n_c	$[V]-\langle V_c\rangle$ x100
	14	54	10.80	10.82	2	- 2	10.89	6	- 9
	15	55	10.85	10.82	1	+ 3	11.07	3	-22
	16	56	10.89	10.80	4	+ 9	10.74	6	+10
	17	57	10.94	10.47	1	+47	10.74	3	+11
	18	58	10.98	10.73	2	+26	11.02	4	- 4
	19	59	11.02	11.41	1	-39	11.21	1	-18
	21	61	11.11	10.98	1	+13	11.24	2	-13
	22	62	11.15	11.06	2	+ 9	11.31	2	-16
	23	63	11.19	10.98	1	+21	11.20	1	- 1
	24	64	11.23	11.58	1	-35	11.17	2	+ 6
	25	65	11.27	11.76	1	-49	11.57	1	-30
	26	66	11.31	11.10	2	+21	10.92	1	+39
	27	67	11.35	11.60	3	-25	11.20	3	+15
	28	68	11.39	11.42	1	- 3	11.32	1	+ 7
	29	69	11.43	12.0:	1	-57	11.54	2	-11
	30	70	11.47	11.13	1	+34	11.37	1	+10
	31	71	11.50	11.43	2	+ 7	11.59	3	- 9
Nov	3	74	11.62	11.29	1	+33	11.43	1	+19
	4	75	11.65	11.46	1	+19	11.26	1	+39
	5	76	11.69	11.96	3	-28	11.75	4	- 6
	7	78	11.76	11.58	2	+18	11.70	1	+ 6
	9	80	11.83	12.03	1	-20	11.85	1	- 2
	10	81	11.86	12.17	2	-31	12.32	2	-26
	14	85	11.99	12.32	1	-33	12.15	4	-16
	15	86	12.02	11.99	3	+ 3	11.98	2	+ 4
	18	89	12.12	11.94	1	+18	12.08	1	+ 4
	24	95	12.30	12.30	1	0	12.32	1	- 2
	26	97	12.36	12.40	1	- 4			
	27	98	12.39				12.40	1	- 1
	28	99	12.42	12.56	2	-14	12.41	2	+ 1
	30	101	12.48	12.58	1	-10	12.40	2	+ 8
Dec	1	102	12.50	12.4:	1	+10	12.40	1	+11
	2	103	12.53	12.82	1	-29	12.62	1	- 9
	3	104	12.56				12.57	1	- 1
	4	105	12.59	12.85	1	-26	12.55	1	+ 4
	9	110	12.73	12.82	1	- 9	12.72	1	+ 1
	10	111	12.75	13.20	1	-45	12.79	1	- 4
	11	112	12.78		1		12.84	1	- 6
	18	119	12.96		1		13.00	1	- 4
	28	129	13.20	12.85	1	+35	12.99	1	+21
	29	130	13.22	13.88	1	-66	13.00	1	+22
	30	131	13.25	13.50	1	-25	13.06	1	+19
Jan	2	134	13.32	14.47	1		13.5	1	-18
	5	137	13.38		1		13.3	1	+ 8
	31	163	13.92		1		14.0	1	- 8

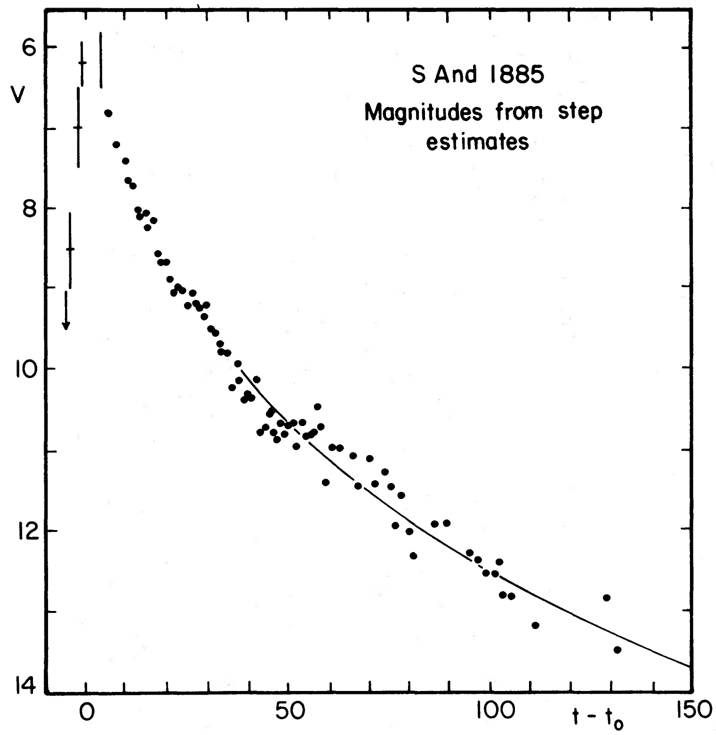

FIG. 3.—First approximation light curve from Class A, B, C observations reduced to V system, but not corrected for personal equation

from the values $[V]$ predicted by equation (3) shows no systematic difference during the first three months: on the average $\langle [V] - V \rangle = +0.03 \pm 0.06$ ($N = 39$) with a standard deviation $\sigma = 0.35$, and the median is 0.00.

iii) *Sets differing from the standard curve by a constant only.*—The study of systematic errors (see § IV*c*) shows that at magnitudes $V < 11.0$ several sets of observations differ from the standard curve by a constant only; this zero point difference is generally less than ± 0.3 mag[6] and on the average is a negligible $\langle [V] - V \rangle = +0.03 \pm 0.06$ (9 sets from 8 observers for a total of 100 observations). The standard deviation of the mean residuals is $\sigma = 0.19$ mag (9 sets).

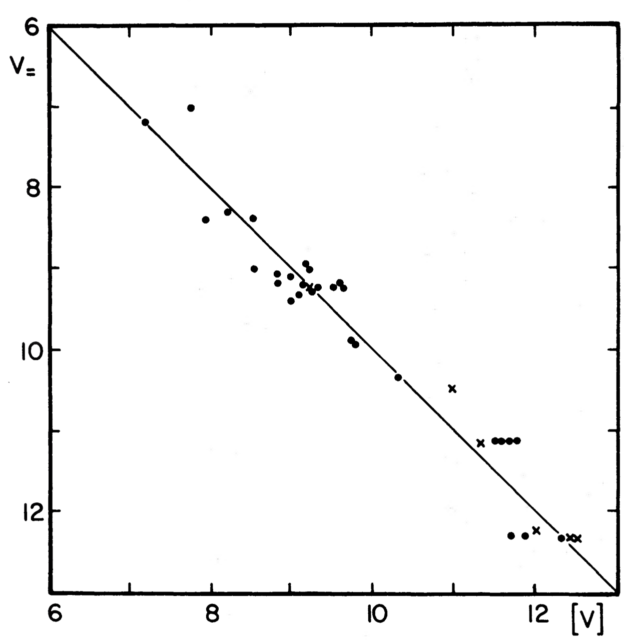

FIG. 4.—Comparison of magnitudes $[V]$ calculated from eq. (3) and magnitudes V deduced from observations of equality with comparison stars.

c) Systematic Errors

As noted in § III, systematic errors arising from personal equation are in evidence, even after reduction of the comparison stars to the V system. In the best cases, the systematic error is merely a constant zero-point shift; for several others, a linear function gives a good enough fit; for a few, a more complicated variation is indicated. Overall, there is no systematic trend suggesting a revision of equation (3) one way or the other.

Finally, observations in Group D (no specified magnitude scale) were reduced to the system defined by the mean curve as above. Isolated or casual observations are of little value; longer series (Espin, Trouvelot, the Baxendells) were graphically reduced. The corrected magnitudes V_c were included in Table 4 and used to calculate the final mean points $\langle V_c \rangle$. The definitive light curve is shown in Figure 5 and a comparison with the ephemeris (eq. 3) is shown in Figure 6. The lower part of Figure 6 is a plot of 3 day moving averages of the residuals $[V] - \langle V_c \rangle$. No significant departure in excess of ± 0.1 mag is indicated.

A graph of the residuals $[V] - m$ of the casual observations shows an enormous scatter, covering a range in excess of three magnitudes; such observations contribute very little useful information and have not been used in the construction of the mean light curve. Some of the uncertainties and irregularities noted in previous attempts to construct a mean light curve are due to the unwarranted inclusion of such observations.

[6] The Parkhurst set, which has a large zero point error of +0.64 mag, was excluded.

TABLE 5

OBSERVATIONS OF EQUALITY IN MAGNITUDE WITH COMPARISON STARS[a]

Date	Observer	Comparison[b]	V(S)	$[V]-V$
Aug 29	Hartwig	S = No. 27	7.20	0.00
Sep 2	Numsen	S ≈ No. 2	7.01	+0.76
Sep 2	Young	S = No. 2	7.01	+0.76
Sep 3, 4	Barnard	S = No. 22	8.39	−0.43
Sep 6	Lohse	S ≥ No. 22	8.3:	−0.06
Sep 9	Lohse	S = No. 22	8.39	+0.16
Sep 9	Numsen	S ≥ No. 14	9.0:	−0.45
Sep 12	Lohse	S(0.1–0.2) Nos. 14 and 7	9.1:	−0.28
Sep 12	Numsen	S ≥ Nos. 14 and 7	9.2:	−0.38
Sep 14	Bigourdan	S = No. 29	9.13	−0.14
Sep 14	Numsen	Nos. 14 and 7 ≥ S	9.4:	−0.41
Sep 15	Wolfer	S = No. 42	9.32	−0.25
Sep 16	Flammarion	S = No. 14	9.20	−0.05
Sep 16	Numsen	S ≥ Nos. 14 and 7, S ≤ No. 24	8.95	+0.20
Sep 17	Numsen	S = Nos. 14 and 7	9.24	−0.01
Sep 17	Vogel	Nos. 14 and 7 ≥ S	9.3:	−0.07
Sep 17	Winlock	No. 29(0.1)S	9.23	0.00
Sep 17	Wolfer	S = No. 21	9.03	+0.20
Sep 18	Numsen	S = Nos. 14 and 7	9.24	+0.07
Sep 21	Peek	S = Nos. 14 and 7	9.24	+0.28
Sep 22	Kammermann	No. 29 ≥ S	9.2:	+0.39
Sep 23	Wolfer	S = Nos. 21 and 11	9.24	+0.41
Sep 24	Numsen	S ≥ No. 1	9.9:	−0.18
Sep 25	Numsen	S ≈ No. 1	9.96	−0.18
Oct 4	Bigourdan	S = No. 3	10.35	−0.04
Oct 18	M. Hall	S = No. 6	10.47	+0.51
Oct 26	Lohse	S = No. 9	11.13	+0.18
Oct 31	M. Hall	S = No. 8	11.14	+0.36
Nov 4	Copeland	S = No. 8	11.14	+0.41
Nov 5	Peek	S = No. 10	12.32	−0.63
Nov 5	Copeland	S = No. 8	11.14	+0.55
Nov 7	Copeland	S = No. 8	11.14	+0.62
Nov 10	Allen	S = No. 10	12.32	−0.46
Nov 14	Young	S = No. 10	12.32	−0.33
Nov 15	Dunér	S = No. 12 or S(1s) No. 12	12.28	−0.26
Nov 16	Cortie	No. 10 ≥ S	12.4:	−0.34
Nov 24	Cruls	S = No. 10	12.32	−0.02
Nov 28	Lohse	S = No. 10	12.32	+0.10
Dec 1	Lohse	S ≈ No. 10	12.32	+0.19
Mean (N = 39)				+0.03
Mean error				0.06
Standard deviation				0.35

[a] For references see Table 2.

[b] Comparison of S And with stars listed in Table 3; 0.1 means 0.1 mag; 1s means 1 step.

V. THE COLOR CURVE

a) Color Scale and Color Index

Nearly all observers recorded the striking orange color of the star in 1885 August and early September, but few made comparisons with other stars allowing us to derive the color index on a modern scale. Nevertheless, those few are in good agreement (Table 6) to indicate a mean color index $\langle B-V \rangle = +1.31 \pm 0.06$ ($N = 6$, $\sigma = 0.16$) for the time interval September 4–8 (15–19 days past maximum) and to fix the zero point of the color scale that can be derived from the qualitative color estimates (Table 7A).[7]

[7] A few observers reported a greenish tint in early September (e.g., Brooks with a 23 cm reflector on September 3, Woodside with a 16 cm reflector on September 6), suggesting that the chromatic correction of refractors might be responsible for the yellow or reddish color reported by others. This is unlikely because several observers equipped with larger reflectors confirmed the reddish color, e.g., Franks with a 28 cm reflector on September 3 ("decidedly yellowish"), Tarrant with a 26 cm reflector on September 4 ("decidedly reddish-yellow ... not unlike Arcturus"), and, especially, Rosse—presumably with the 172 cm reflector at Birr Castle—on September 7 ("color ... much the same as Aldebaran").

A complete listing of all available color estimates and their color scale equivalents C will be given elsewhere (de Vaucouleurs 1985*b*). The time averages $\langle C \rangle$ are listed in Table 7B. Approximate corresponding values of the $B-V$ color index, calculated with the equation

$$B-V = -0.25 + 0.8\sqrt{C}\,, \tag{4}$$

are shown in Figure 7. It is apparent that S And was most strongly colored at or shortly after maximum light and turned to a more whitish "average star" color about three weeks later. Whether the star became actually "bluish," as some observers asserted, may be doubted. Star colors are difficult or impossible to ascertain at light levels less than 4 mag above the detection threshold, which for most observers would have been below magnitude 10, reached at the end of September. It is not surprising, therefore, that few color estimates were recorded after mid-October.

Discounting, then, a few aberrant reports, the color estimates lead to a coherent color curve with a maximum near $B-V \approx 1.3$ at the end of August and in the first week of Sep-

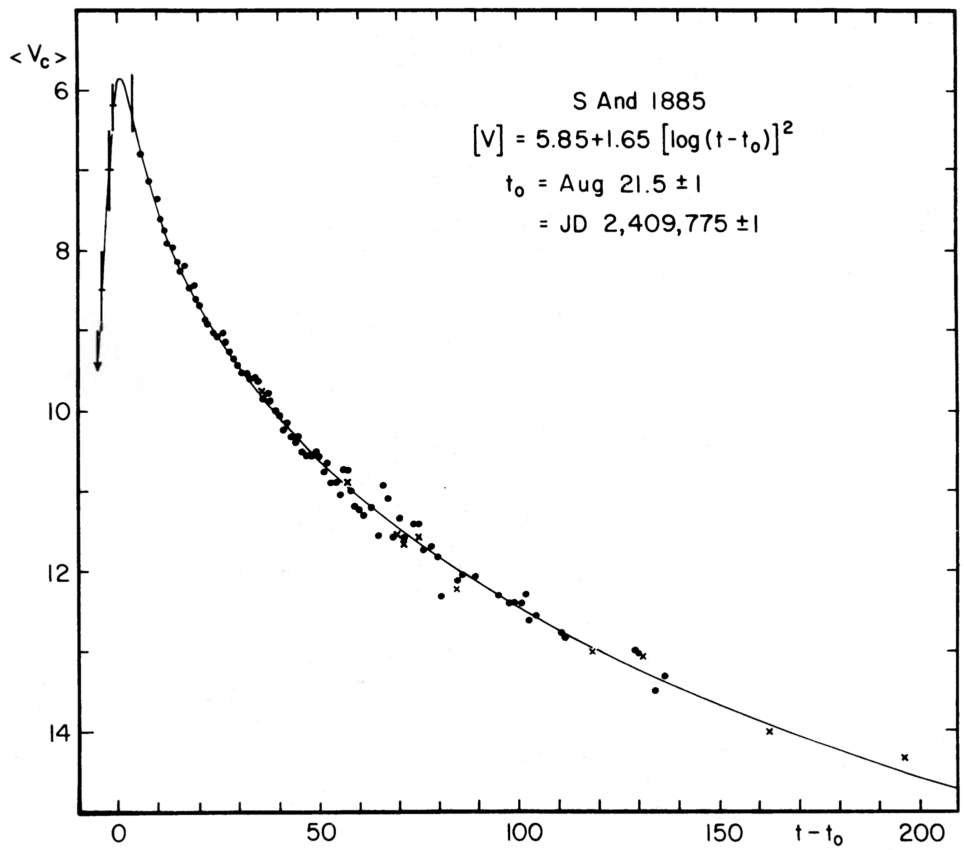

FIG. 5.—Definitive light curve of S And from 300 observations reduced to V system and corrected for personal equation. Dots are daily mean points, crosses are single last observations.

tember, about 10–20 days past maximum light, rapidly declining to $B-V \approx 1.1$ by mid-September or ~ 25 days past maximum, then more slowly to $B-V \approx 0.9$ at the end of September and, possibly, $B-V \approx 0.6$ toward the end of October. This behavior is similar to that of Type I supernovae in the later phases of their decline. However, the rise to maximum reddening within a few days of maximum light is unparalleled. In Figure 8 we compare the "standard" color-magnitude evolution of Type I supernovae with the corresponding curve for S And. While the declining branch *BCDE* could be roughly reconciled with the standard Type I curve for plausible values of the extinction and reddening (see below), as shown by the dashed line *B′C′D′E′*, the initial branch *AB* cannot. The sudden decline (*BC*, *B′C′*) is also atypical.

b) Color Excess and Extinction

The color at maximum light ("golden gelb" on August 20, according to Hartwig), when normal Type I supernovae are

TABLE 6

COLORS FROM DIRECT COMPARISON WITH STARS

Date	Observer	Description	$\langle B-V \rangle$
Sep 4	Maunder	"orange-yellow, like Arcturus and Aldebaran"[a]	+1.38
Sep 4	Tarrant	"color about equal to Arcturus"	+1.23
Sep 5	von Gothard	"gelblicher als α Boötis"	+1.4:
Sep 6	Lohse	"yellow, like that of B-W2 0.896, 0.953, 0.965, 0.1062"[b]	+1.1:
Sep 6	Tupman	"yellow color, similar to Arcturus"	+1.23
Sep 8	Rosse	"reddish-yellow color . . . same as that of Aldebaran"	+1.54
Sep 24	Peek	"more yellow than [Nos. 7 and 14]"[c]	+1.0:
Mean (Sep 4–8)			+1.31
Mean error			0.06
Standard deviation			0.16

[a] $B-V = +1.23$ and $+1.54$.
[b] $\langle B-V \rangle = +1.06 \pm 0.23$.
[c] Nos. 7 and 14 have $B-V = +0.71$ and $+0.99$.

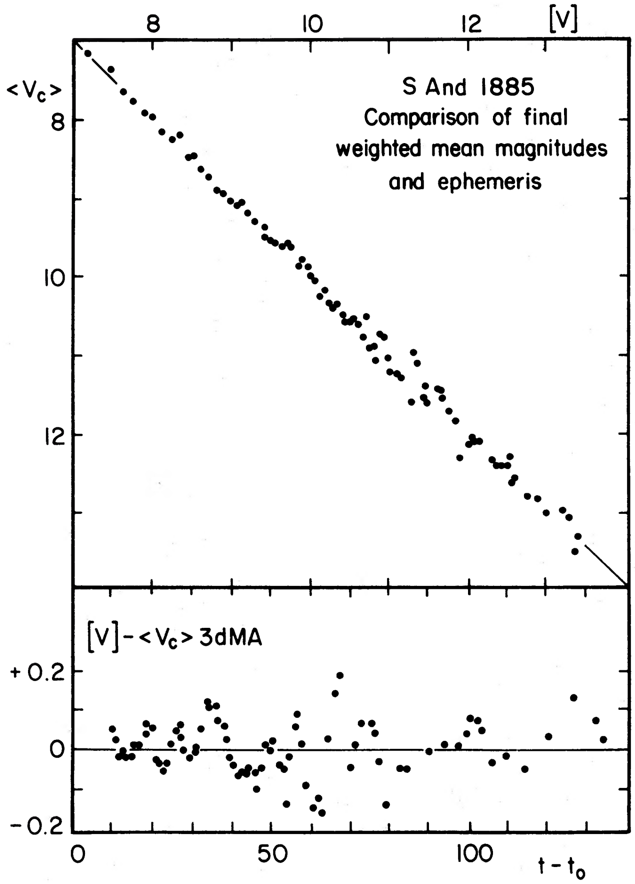

FIG. 6.—Comparison of final weighted mean magnitudes $\langle V_c \rangle$ and ephemeris magnitudes $[V]$. Below, three-day moving averages of $[V] - \langle V_c \rangle$ residuals versus time past maximum $t - t_0$.

white ($B-V \approx 0.0$, after Pskovskii 1977) might suggest that S And was highly obscured and reddened, but we do not believe that such was the case for the following reasons:

i) The galactic foreground obscuration in the M31 field is fairly well established; the all-sky formula used in the *Second Reference Catalogue* (de Vaucouleurs, de Vaucouleurs, and Corwin 1976, hereafter RC2) predicts $A_B = 0.41$ mag ($A_V = 0.31$) and a color excess $E(B-V) = 0.10$, which is in good agreement with direct determinations from field star colors, viz., $E = 0.06 \pm 0.03$ (van den Bergh 1964), 0.12 ± 0.04 (Schmidt-Kaler 1967), and 0.11 ± 0.02 (McClure and Racine 1969). Internal extinction is more difficult to estimate; the RC2 formulae for extinction of the integrated magnitude of a galaxy having the inclination of M31 predict $A(i) - A(0) = 0.36$ (B) and 0.27 (V) and, possibly, $A(0) = 0.17$ (B) and 0.12 (V) for a star in the equatorial plane, leading to a possible internal color excess of 0.12 and a total $E(B-V) = 0.22$.

ii) That the average extinction is not large near the center of M31 is also attested by the mean color index of the nucleus, about $\langle B-V \rangle = +1.05$ (de Vaucouleurs 1958), which is normal for a galaxy of type Sb having the inclination and galactic latitude of M31. The integrated color of M31 as a whole, $\langle B-V \rangle = +0.91 \pm 0.02$ (de Vaucouleurs 1958; RC2) gives the same indication: after correction for inclination and galactic extinction according to the RC2 recipes, the face-on color is $(B-V)_0 = +0.74$, which may be compared with the standard mean color of Sb galaxies similarly corrected, $\langle (B-V)_0 \rangle = +0.737 \pm 0.009$ (de Vaucouleurs 1977).

iii) It is, of course, always possible to invoke the accidental presence of a small dark cloud in front of the star. However, such a cloud would have to be small enough to remain invisible on direct photographs, because none of the well-known dark clouds in the vicinity of the nucleus of M31 coincides with the position of S And (see Fig. 2). A more serious objection is that the postulated color excess of 1.2–1.3 mag would conflict with the observed maximum color of the star, +1.2, corrected for galactic extinction only, while the normal maximum color index of Type I supernovae is +0.9 to +1.0 (Pskovskii 1971; BCR). This would suggest an internal reddening of at most 0.3 mag, corresponding to a total V band extinction of ~1.0 mag. Further, the postmaximum color index of ~+0.6 is also inconsistent with a total reddening in excess of 1 mag, because the intrinsic color of Type I supernovae in their declining phase is generally positive (Pskovskii 1971; BCR).

Finally, the internal extinction hypothesis does nothing to account for the apparent absence of a rapidly increasing reddening during the maximum phase. Because of this discrepancy between the color evolution of S And and that of any other known type, we will refrain from deriving a definite value for the color excess by comparison of the color curve with

TABLE 7

A. COLOR SCALE

Step	Description	$\langle B-V \rangle$[a]
0.0......	"decidedly bluish tinge"	−0.25
0.5......	"blue whitish," "very slightly bluish"	+0.32
1.0......	"white stars," "ordinary white stars,"[b] "pale white," "pale greenish"	+0.55
1.5......	"whitish," "creamy white," "whiter than before," "more yellowish [than before] or not colored," "yellowish white"	+0.73
2.0......	"slightly yellowish," "yellowish," "a little yellow"	+0.88
2.5......	"dull yellow," "yellow," "pure yellow"	+1.01
3.0......	"full yellow," "golden yellow"	+1.14
3.5......	"like Arcturus," "orange yellow," "color of D lines," "pink yellow"	+1.25
4.0......	"light orange," "weakly orange," "reddish yellow," "more yellow than Arcturus"	+1.35
4.5......	"dull orange," "orange," "brilliant orange," "deep orange"	+1.45
5.0......	"yellowish red," "reddish orange," "slightly reddish," "rather reddish," "same as Aldebaran"	+1.54
5.5......	"reddish," "ruddy"	+1.63

B. MEAN COLOR ESTIMATES

Date	$\langle C \rangle$	Mean Error	N	$\langle B-V \rangle$[a]	Mean Error
Aug 20	3.5	...	1	1.25	...
Aug 30–Sep 2	3.56	0.42	16	1.26	0.09
Sep 3, 4	3.59	0.30	23	1.26	0.06
Sep 5–7	3.70	0.32	17	1.29	0.07
Sep 8, 9	3.74	0.38	12	1.30	0.07
Sep 11–14	2.50	0.44	9	1.01	0.11
Sep 15–20	2.07	0.40	7	0.90	0.11
Sep 24–27	2.08	0.43	6	0.90	0.12
Sep 28–Oct 5	1.81	0.30	8	0.83	0.08
Oct 7–17	1.29	0.32	7	0.66	0.11
Nov 3–Dec 11	1.20	0.38	5	0.63	0.12

[a] Calculated as $\langle B-V \rangle = -0.25 + 0.8\sqrt{C}$.

[b] The average color index of 16 comparison stars fainter than $V = 11.0$ is $\langle B-V \rangle = +0.57$ (see Table 3).

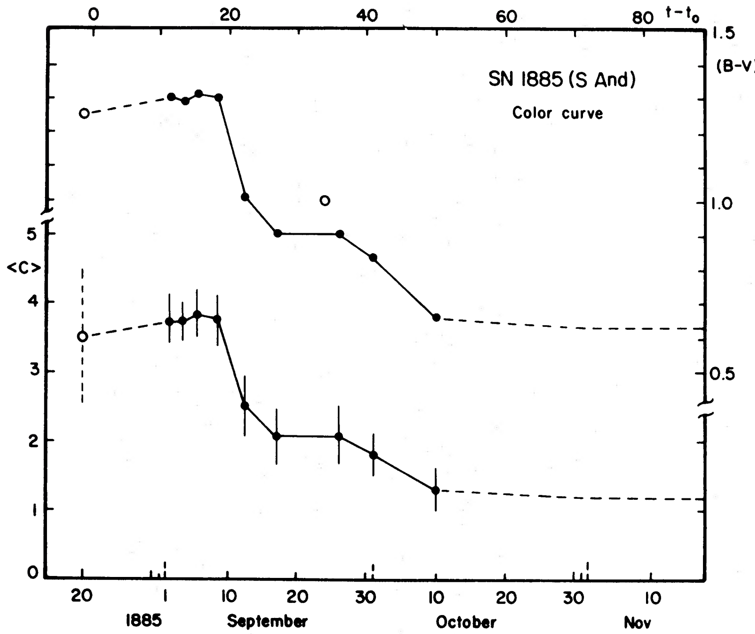

FIG. 7.—Mean color curve on $\langle C \rangle$ scale (*below*) and on approximate $(B-V)$ scale (*above*)

some assumed "standard" curve, but will merely suggest that the total color excess is unlikely to exceed ~ 0.3 mag, of which 0.1 originates in our Galaxy and 0.2 or less in M31. The dashed line in Figure 8 shows the color curve of S And corrected for a tentative $E(B-V) = 0.3$, $A_V = 1.0$ mag.

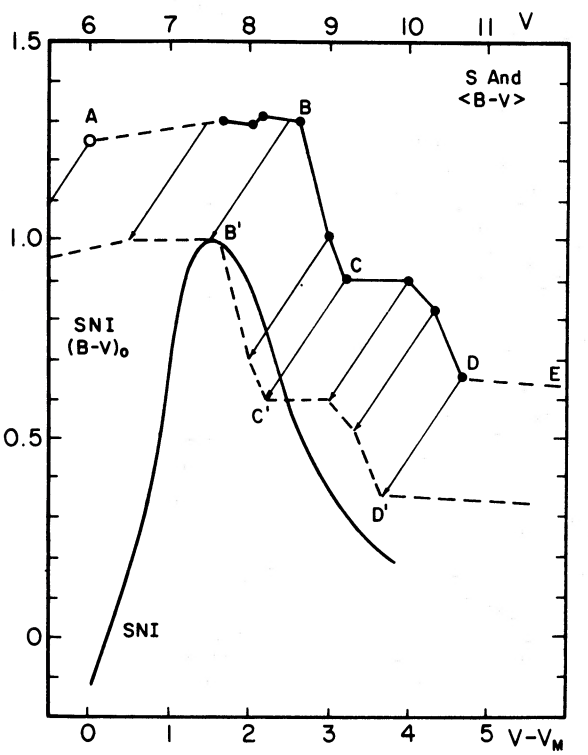

FIG. 8.—Color-magnitude evolution of S And compared to the average of Type I supernovae. Arrows and dashed line shows effect of correcting for $E(B-V) = 0.3$ and $A_V = 1.0$ mag. Orange color at maximum was not caused by extinction.

c) B-Band Light Curve and Decay Parameters

The V light curve represented by equation (3) and the $B-V$ color curve of Figure 7 can be combined to give an approximation of the B-band light curve (Fig. 9) which may be more directly comparable to modern light curves of Type I supernovae.

It has often been asserted that the decay rate of S And was much too fast for a Type I supernovae. This is true enough if the B-band light curve is compared with the average of all Type I supernovae (BCR). For example, whereas S And took only 5, 11, and 26.5 days to drop 1, 2, and 3 mag from its (extrapolated) maximum ($B \approx 7.1$), the average of Type I supernovae takes 14, 23, and 55 days, or ~ 2.3 times longer. However, there is a large range in the observed rates of decay, and some objects match closely, and possibly exceed, the rate of S And. For example, SN 1939b in the Virgo Cluster E5 galaxy NGC 4621 (Fig. 9) had an initial rate of decay of 0.25 mag day^{-1} versus only 0.175 mag day^{-1} for S And. According to Rust (1974), the rate of decay parameter Δt_c, defined as the number of days it took for the luminosity to decline from $m(\max) + 0.5$ to $m(\max) + 2.5$, was 8.8 for SN 1939b versus 9.1 for S And (or 8 versus 13 from Fig. 9). However, the rate of rise may have been faster for S And (possibly 0.7 mag day^{-1} vs. 0.4 mag day^{-1} for SN 1939b). In any case, it is clear that the high initial decay rate of S And is not unique among Type I supernovae.[8]

d) Absolute Magnitudes at Maximum

The adopted apparent magnitudes at maximum $V(0) = 5.85$ and $B(0) = 7.10$, the limits on the color excess $0.1 \leq E(B-V) \leq 0.3$, and the adopted distance modulus of M31, $\mu_0 = 24.07 \pm 0.16$ (de Vaucouleurs 1978*b*), lead to the follow-

[8] It is evident that such ultrafast supernovae will be more difficult to discover for two reasons: (1) the short time spent near maximum, and (2) the rate of decline—luminosity relation if, as seems possible, the faster types have fainter maxima (Rust 1974; de Vaucouleurs and Pence 1976; Pskovskii 1977). Hence, they may not be as rare as these two examples might suggest.

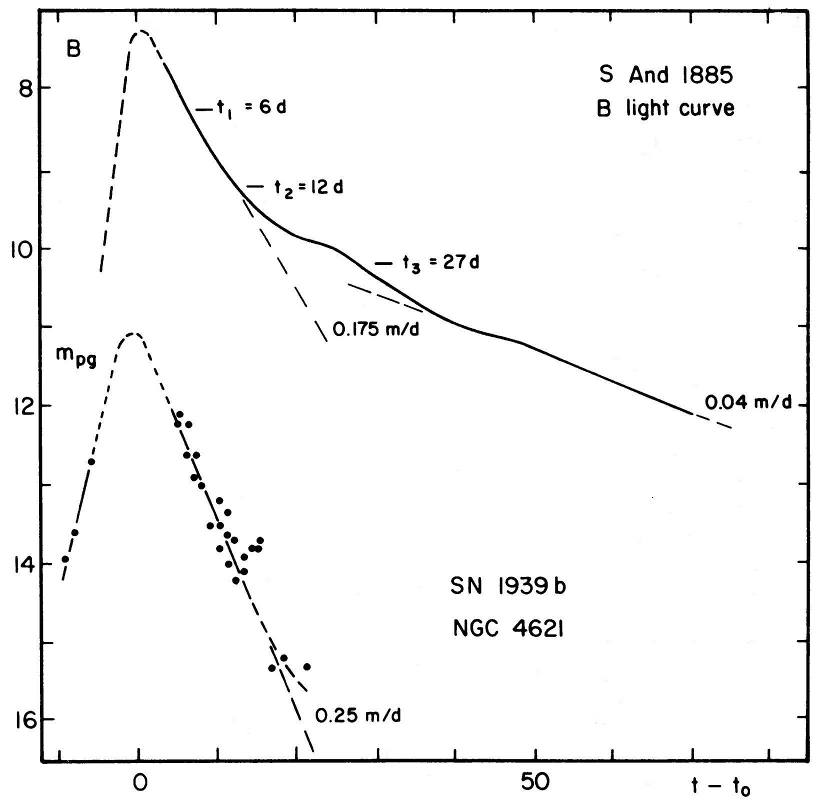

FIG. 9.—Probable B-band light curve of S And inferred from Figs. 5 and 7. Comparison with photographic light curve of Type I SN 1939b in NGC 4621. Premaximum rise was probably faster in S And, but postmaximum decay was slower.

ing range of possible values for the absolute magnitudes at maximum:

$$18.55 \leq -M_V \leq 19.21 \; ; \quad 17.40 \leq -M_B \leq 18.26 \, .$$

This may be compared to $-M_V = 18.55 \pm 0.3$ for Tycho's supernova (de Vaucouleurs 1985*a*) and to $-M_B = 18.5 \pm 0.2$ for the average of Type I supernovae on the short distance scale (de Vaucouleurs 1979). Both are best compatible with the assimilation of S And to Type I if the color excess is as high as 0.3, as was also suggested by Figure 8. However, considering the uncertainties in the apparent magnitudes at maximum, which could be as large as 0.5 mag in each case, and the remaining uncertainty in the distance modulus of M31 itself, which could be as large as 0.3 mag (2 σ), the lower values of the extinction are by no means excluded. Within the accuracy of the data, $M_V = -19$ and $M_B = -18$ are reasonable values for the absolute magnitudes of S And at maximum, with the unusual intrinsic color $(B-V)_0 = +1.0$. The value of M_B is consistent with the rate-luminosity relation for the less luminous group of Type I supernovae (Rust 1974; de Vaucouleurs and Pence 1976).

VI. THE SPECTRUM

The marginal visual spectroscopic observations of S And were reviewed by C. Payne-Gaposchkin (1936) and led her to the conclusion that the spectral features, if any, are mainly unidentifiable—except for two possible coincidences with emission lines at λ5325 and λ5575 in the spectra of normal *novae*.[9] A reexamination of all available descriptions of the spectrum, including some not considered in Mrs. Gaposchkin's review, leads us to different conclusions; in fact nearly all the features noted, however marginally, in the spectrum of S And by the spectroscopists of 1885 correspond closely to known intensity maxima or minima in the spectra of Type I supernovae.

A complete tabulation of all the recorded or suspected spectral features with the detailed comments of the original observers will be found elsewhere (de Vaucouleurs 1985*b*). The gist of their observations is collected in Table 8. Table 9 presents a summary of the measured or estimated wavelengths λ and their mean values λ_0, corrected to the rest frame of M31. The last two columns of the table give, from a compilation of various sources (Zwicky 1965; Greenstein and Minkowski 1973; Kirshner *et al.* 1973; Oke and Searle 1974; Bolton *et al.* 1974; Kirshner and Oke 1975; Patchett and Wood 1976; Kirshner, Arp, and Dunlap 1976; Ciatti and Rosino 1977), the range and the mean of the rest wavelengths of the most prominent emission features in the spectra of Type I supernovae. The agreement with the bright "nodes" observed in the spectrum of S And is unexpectedly close; the standard deviation between the

[9] Later, these observations were rediscussed by Minkowski (1939), who cautiously concluded only that "it is not impossible that in the region above λ5000 the spectrum of S Andromedae may have been similar to the spectra of [the Type I] supernovae [in] IC 4182 and NGC 1003; the spectra below λ5000 may have been different." A more recent claim (Chugaj 1983) that S And was of Type II, based mainly on Parenago's (1949) light curve and the possible identification of one line with Hβ, appears to us to conflict with most other data.

TABLE 8

Spectroscopic Observations of S Andromedae

Date	Description of Spectrum	Observation Number
Sep 1–3	Continuous, yellow and red strong, blue and violet abnormally weak, traces of bright lines (in red and yellow) diffuse dark bands suspected in blue between F and G (~4500 Å) and at limit of green and yellow (~5700 Å)	1–6
Sep 4–6	Continuous, strong in red, very strong from D to F, faint in blue, very faint in violet, bright lines suspected in blue-green (~4890? Å) and red	7–14
Sep 7–9	Continuous, faint in blue midway between F and G, brighter near G, strong in red with bright line near C, and 3–5 bright lines between D and b, near 5875 Å (D_3), 5575 Å, 5315 Å; another near F at 4865 Å	15–19
Sep 10–15	Continuous with maximum at 5444 Å, visible extent 4319–6600 Å or 4350–6700 Å, bright lines or bands measured near 5327, 5482 Å, and suspected near ~4822 Å and ~5880 Å (close to D)	20–28
Sep 16–20	Continuous, red weaker, strong in yellow and green, blue well seen, violet weak, faint lines suspected near C, and F (4900 Å?), two better seen in yellow (near D), green (5480 Å?)	29–33
Sep 21–Oct 2	Weaker continuum, visible extent 4676–5758 Å, bright lines seen again near D (~5850 Å) and in green (~5482, ~5327 Å), others measured at 4892, 5140, 5468 Å, one suspected near 5575 Å	34–37
Oct 9–Nov 5	Spectrum continuous, but "highly interrupted . . . more than one definite bright line, brightest in green"	38–40

Observation Numbers and Sources.—(1) Young (*SM* 4, 282). (2, 20, 22, 26, 33, 36, 37, 39) Copeland (*MN* 47, 49). (3, 21, 32) Vogel (*AN* 112, 283, 302, 387). (4) Ricco (*AN* 112, 300; *Nat* 32, 523). (5) Roberts (*AR* 23, 253; *JLAS* 4, 3). (6, 19, 23) Lohse (*MN* 46, 299). (7, 24, 35) Maunder (*MN* 46, 19; *Obs* 102, 335). (8, 16, 28, 30, 31) Konkoly (*AN* 112, 286; *Obs* 102, 334; *O'GB* 4, 8). (9) Noble (*EM* 1070, 78). (10) Hasselberg (*AN* 113, 19). (11, 13) Gothard (*AN* 112, 390). (12) Tupman (*Kno* 203, 238). (14, 27) Klein (*WA* 28, 292, 335). (15) Rosse (*Nat* 32, 436). (17) Sherman (*AmJS* 30, 378; *AJ* 7, 66; *MN* 47, 14). (18) Huggins (*Obs* 8, 333; *Nat* 32, 465). (25, 38) Cortie (*MN* 46, 22; unpubl.). (29, 40) Backhouse (*MN* 48, 108). (34) Seabroke (*Nat* 32, 523). For abbreviations see Table 2B.

TABLE 9

Observed and Rest Wavelengths in Spectrum of S Andromedae Compared with Spectrum of Type I Supernovae[a]

Measured or Estimated λ (Å)	Source	Date (1885)	$t - t_0$ (days)	Mean λ_0 (Å)	SN I Range (Å)	SN I Mean (Å)
4716	Copeland	Sep 20	30	4773:	4765–4790	4777
4822	Copeland	Sep 10	20			
4861:	Konkoly	Sep 7	17	4890	4900–4950	4929
4865	Sherman	Sep 5	15			
4892 ± 23	Copeland	Oct 1, 2	41, 42			
4900:	Konkoly	Sep 17	27			
5140 ± 26	Copeland	Oct 1, 2	41, 42	5145	5080–5200	5145
5315 ± 45	Sherman	Sep 5	15	5326	5260–5358	5310
5327	Maunder	Sep 11, 30	21, 40			
5444	Copeland	Sep 10	20	Maximum of continuous spectrum		
5468 ± 50	Copeland	Oct 1, 2	41, 42	5480	5410–5500	5453
5482	Maunder	Sep 11, 15	21, 25			
5575 ± 65	Sherman	Sep 5	15	5580	5550–5615	5592
5575:	Maunder	Sep 30	40			
5850:	Seabroke	late Sep	35:	5880	5850–5925	5887
5876:	Konkoly	Sep 7	17			
5890:	Maunder	Sep 11	21			
6563:	Konkoly	Sep 7	17	6568:	6500–6600	6550
6563:	Konkoly	Sep 16	26			

[a] Standard deviation between corresponding features in spectrum of S And and mean SN I spectrum: 20 A.

wavelengths of eight corresponding features is only 20 Å, a quantity which is, if anything, smaller than the errors in the old observations and the scatter in the modern data. The mean visual spectrum is summarized in Figure 10 (Plate 12). Compared to charts of the spectral evolution of Type I supernovae by Minkowski (1939) and others, the similarities are striking and leave little doubt, in our opinion, that S And was a Type I supernova, in both the shape of its light curve (§ IV) and its spectral characteristics, in spite of its abnormal color at maximum and unusually fast rise. Table 9 and Figure 10 are also tributes to the skill and competence of the observers in these heroic pre-photographic times of astronomical spectroscopy.[10]

VII. THE NATURE OF S ANDROMEDAE AND THE SEARCH FOR ITS REMNANT

a) *Nova or Supernova?*

Although the present reanalysis leaves little room for an identification of S And as other than a peculiar Type I supernova, the possibility that it might have been a Galactic nova accidently projected in front of M31 needs to be considered. This was already suggested by some commentators in 1885. The arguments for and against the identification of S And as a Galactic nova or as an extragalactic supernova are as follows:

i) The rapid rise to maximum and the rate of decay are perfectly consistent with a fast galactic nova (e.g., Nova Aquilae 1918, Nova Puppis 1942, Nova Cygni 1975). In fact the parameters of the visual light curves of S And and of Nova Cygni 1975 (Young *et al.* 1976) are very similar.

ii) Even the colors near maximum were similar. However, in the case of Nova Cygni, this was clearly due to interstellar extinction, and the color evolution of S And precludes this interpretation (§ V). Novae are intrinsically white at maximum, with $B-V \approx 0.0$ (Bertaud 1945), while S And was yellowish-orange, with $B-V \approx +1.0$, even after correction for allowable external reddening (Fig. 8).

iii) Then, of course, the odds against a distant Galactic nova appearing at the Galactic latitude, $-21°$, of M31 are very great indeed. Because of the rate of decay ($\log t_2 \approx 1.0$–1.1), the absolute magnitude at maximum would have to be in the -9 to -10 range (de Vaucouleurs 1978*a*; Cohen 1985) and the distance modulus correspondingly large, about 15, placing the supposed nova at an extraordinarily large distance, some 3–4 kpc, below the Galactic plane.

iv) Finally, although some of the bright lines or bands seen or suspected in the spectrum could be close to lines seen in the spectra of normal novae, as noted by Mrs. Gaposchkin (§ VI), none of the others is a good match, while most can be easily identified with typical maxima and minima in the spectra of Type I supernovae (Fig. 10). There was no indication of the development of the characteristic nebular spectrum, which was already well known to 19th century spectroscopists, who had seen it in N CrB 1866 and N Cyg 1876 (Lockyer 1892).

Hence, we have little choice but to conclude that, in spite of its peculiarities, S And was an extragalactic supernova in M31, either a peculiar Type I or, possibly, a rare type not yet observed (or recognized) in other galaxies.

b) *The Search for an Optical Remnant*

If, then, S And was a Type I supernova at the adopted distance of M31, $\Delta = 651$ kpc (de Vaucouleurs 1978*b*), where $1'' = 3.156$ pc $= 9.74 \times 10^{13}$ km, a number of interesting consequences for the present location and size of the remnant follow:

i) After 100 yr of expansion the spherical photon shell corresponding to maximum light will have a radius of $R_c = 9.45 \times 10^{14}$ km $= 9''.70$, which should give a first-class parallax for M31 if it could be observed against the brilliant background of the central part of the galaxy. Since nothing has ever been seen, either there is not enough dust to produce appreciable scattering, or the background is too bright (in the V band it is 5 mag brighter than the normal surface brightness of the night sky). If S And was near the equatorial plane of the galaxy, the light-shell will not reach the nucleus of M31 for another century or so.

ii) After 100 yr of expansion at a typical velocity of 10^4 km s^{-1} (Branch 1980), the gaseous remnant should have a radius (assuming no deceleration) $R_g = 3.15 \times 10^{13}$ km $= 0''.32$, which could be detectable optically by its emission lines if the progenitor star had sufficient mass, or in the radio continuum if the swept-up interstellar medium had sufficient density. Since nothing has been detected yet in spite of fairly sensitive searches (see below), some upper limits could be placed on either.[11]

iii) After 100 yr of travel (proper motion), the center of the remnant must have moved some distance from its place of birth in an inertial frame whose origin is at the center of the nucleus of M31. The (line-of-sight) velocity dispersion in the spheroid of M31 is $\sigma_v = 150$ km s^{-1} (de Vaucouleurs 1974; Davoust, Paturel, and Vauglin 1985); the maximum space velocity could be $\sim 3\sqrt{3}\sigma_v = 780$ km s^{-1} and, if it were all in the tangent plane, would cause after 100 yr a displacement of 2.46×10^{12} km $= 0''.025$. A more probable proper motion in the tangent plane could be $\sim 0.6745\sqrt{2}\sigma_v = 143$ km s^{-1}, producing after a century a displacement of only $0''.0046$. This indicates that in the search for the radio remnant its proper motion can still be neglected compared to the precision of the astrometry.

c) *The Search for the Radio and X-Ray Remnant*

All attempts to detect radio emission from the remnant of S And have so far failed (Pooley and Kenderdine 1967; de Bruyn 1973; Spencer and Burke 1973; Dickel and D'Odorico 1984). The most recent observations at a wavelength of 6 cm place an upper limit of 0.2 mJy on the flux within a beam of $1''.3 \times 1''.0$ centered at the presumed location of S And. This negative result implies an absolute flux at least one order of magnitude lower than might be expected from an extrapolation of the

[10] Dr. D. Branch has called our attention to the similarities between the spectrum of S And, as reconstructed in Fig. 10, and that of the peculiar, subluminous Type I supernova SN 1983n in M83 (Richtler and Sadler 1983), which was also abnormally weak in the blue and violet and strong in the red, and did not show the typical absorption feature at 6150 Å (Panagia 1984). Another example, SN 1984 in NGC 991, was recently reported by Wheeler and Levreault (private communication). It is difficult to say whether the λ6150 absorption, if present, would have been missed by the spectroscopists of 1885. Nearly all were on the lookout for emission lines; only Vogel reported the two minima near 4500 Å and 5700 Å. Absence of evidence is not evidence of absence.

[11] We have checked that none of the emission line objects found by Ford and Jacoby (1978) near the center of M31, and identified by them as planetary nebulae, is close enough to the position of S And to be a candidate for identification with its remnant. The large, diffuse area of Hα emission discovered by Jacoby, Ford, and Ciardullo (1985) near the center of M31, although centered near S And, cannot be related to the remnant.

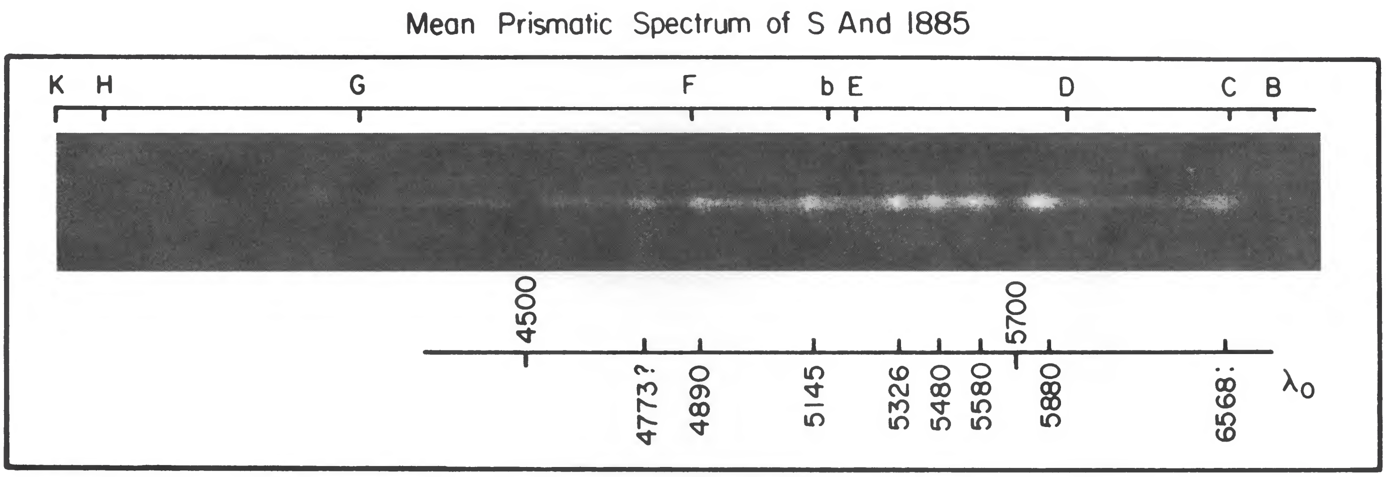

FIG. 10.—An impression of the visible spectrum of S And reconstructed (with exaggerated contrast) from a composite of contemporary descriptions and estimated wavelengths. See Tables 8 and 9.

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$\Sigma - D$ relation for other (older) supernova remnants in M31 (Dickel and D'Odorico 1984). This, in turn, suggests that very little interstellar gas has been swept up by the expanding shell of S And, perhaps because of an abnormally low gas density in the vicinity of the object. The same indication is given by the nondetection of X-ray emission by the HRI instrument of the *Einstein* satellite observatory down to the 10^{37} ergs s^{-1} level in the 0.5–4.5 keV band at 3″ resolution, while some older SN remnants in M31 may have been detected at about twice this sensitivity limit (van Speybroeck and Bechtold 1981).

Complicating the search for the remnant is the surprising fact that the nucleus of M31 itself is undetected at the same resolution and sensitivity; hence the fairly precise differential coordinates of S And relative to the nucleus, measured by many observers in 1885, cannot be relied on to locate the supernova remnant. Absolute coordinates in a well-defined reference system are needed and, although a number of meridian transit observations of S And and of the M31 nucleus were made at various times, it is often difficult or impossible to determine precisely on what system they were made, and reduction to a modern reference frame, such as that defined by the FK4 (Fricke *et al.* 1963), is uncertain.

d) *Coordinates of S Andromedae and of the Nucleus of M31*

A literature search has disclosed several extensive and reliable sets of meridian transit observations of S And in fairly well defined systems, generally that of the *Berliner Jahrbuch* (B.J.) for 1885 (based on Auwers' first *Fundamental Katalog*), or reducible to it by means of nearby reference stars. Surprisingly, the number of reliable determinations of the absolute coordinates of the nucleus of M31 in well-defined systems is more limited, and their agreement is not altogether satisfactory. However, two photographic catalogs, the *Astrographic Catalogue* (Helsingfors Zone; Donner and Furuhjelm 1925, hereafter AC) and the AGK3, included the nuclei of M31 and M32 and can be used to define a frame of reference based on the FK4. The numerous measurements of differential coordinates between S And, the M31 nucleus, and field stars can then be used to provide cross ties and strengthen the net of relative and absolute positions.

The main weakness is that the proper motions listed in AGK3 were determined over the short time base of less than 30 yr between the epochs of AGK2 (ca. 1928) and AGK3 (ca. 1957), resulting in typical errors of 0″.01.[12] Projected over the much longer time interval of 64 yr between the epochs of the AC plates of M31 (1893) and of AGK3, this could lead to errors of several tenths of an arc second. We have attempted to reduce this source of error by deriving improved proper motions through a comparison of AGK3 and AC positions (the latter reduced to AGK3 by a simple zero point correction of $-2''.12 \pm 0''.05$ in R.A., and $-0''.27 \pm 0''.04$ in decl.), but it is clear that a definitive solution must await the determination of more precise proper motions over a much longer time base using new astrometric plate material.

For the present, we will merely list (Table 10) our current adopted mean positions resulting from a combination of both

[12] This is illustrated by the nonsignificant "proper motions" of M31 ($-0''.015$, $-0''.025$) and M32 ($-0''.002$, $-0''.005$) listed in AGK3.

TABLE 10

A. ABSOLUTE COORDINATES OF M31 NUCLEUS AND OF S ANDROMEDAE

OBJECT	N	n	R.A. (1885.75)	Decl. (1950.0)	R.A. (1885.75)	Decl. (1950.0)	SOURCE
M31(N)	AC, AGK3		00ʰ36ᵐ30ˢ.332	+40°38′32″.55	00ʰ40ᵐ00ˢ.13	+40°59′42″.7	1
	2	2	0.012	0.15			
M31(N)	B.J., SAO		00 36 30.356	+40 38 32.28			2
	5	22	0.022	0.05			
S And	B.J.		00 36 29.048	+40 38 28.09	00 39 58.84	+40 59 38.5	3
	6	30	0.012	0.12			
S And	No. 29		00 36 29.044	+40 38 28.21			4
	4	13	0.011	0.06			

B. DIFFERENTIAL COORDINATES OF S ANDROMEDAE AND OF STAR NO. 10[a]

Vector	N	n	Separation	p.a.	$\Delta\alpha \cos \delta$	$\Delta\delta$	Source
$N \to S$	8	30	15″.9 ± 0″.1	255°.6 ± 0°.2	−15″.4	−3″.95	5
$N \to a$	10	51	124.75 ± 0.1	261.28 ± 0.05	−123.3	−18.9	6
$S \to a$	9	55	109.35 ± 0.1	262.15 ± 0.1	−108.3	−14.95	7

NOTES.—N, n = number of indepedent sources, number of nights. Second line of each row in 1885.75 position gives mean error.

[a] Equinox and epoch 1885.75. Precession in p.a. is only +7′ per century or +0°.075 from 1885.75 to 1950.0.

SOURCES.—(1) AGK3 (epoch 1957.8, equinox 1950.0), AC (epoch 1893.4, equinox 1900.0) corrected to AGK3 system by zero-point corrections of −2″.12 in R.A., −0″.27 in decl. from 23 stars in common within 1° of M31 nucleus. (2) Four meridian circle sources (Bonn, Dun Echt, Leipzig) in B.J. system, reduced to AGK3 system, and one photographic in SAO system (de Vaucouleurs and Leach 1981). (3) Five meridian circle sources (Berlin, Bonn, Dun Echt, Vienna, Washington) in B.J. system, reduced to AGK3 system by means of reference stars in Andromeda. (4) Four sources (three micrometric, one transit circle [Washington]) of differential coordinates from reference star B-W2 (Bessel-Weiss Second Catalog) 0.969 = No. 29, corrected to AGK3 system (00ʰ38ᵐ32ˢ.221, +40°41′16″.74, epoch and equinox 1885.75) with improved proper motion (−0″.005, −0″.008). (5) Mean of eight sets of micrometer measurements (range 253°.6–258°.6, 15″.1–16″.6) weighted by N and by n. (6) Mean of eight sets of visual micrometer measurements (1836–1916) and two photographic differential coordinates (AC, de Vaucouleurs and Leach unpublished) (range 261°.05–261°.47, 124″.5–125″.4) weighted by N and by n. (7) Mean of nine sets of visual micrometer measurements (range 261°.7–262°.6, 108″.3–110″.0) weighted by N and by n.

the absolute (AC; AGK3; meridian circles) and differential (micrometric) observations of the M31 nucleus (N), S And (S), and star a = No. 10, the closest and most frequently used comparison star.[13]

The slight inconsistencies between the differential coordinates give a realistic idea of the magnitude of the residual errors amounting to a few tenths of an arc second. Some further refinements should become possible after reduction of the modern plate material now in progress.

This study could not have been made without the generous help of the many colleagues who located for us some hard-to-get old publications or provided us with copies of unpublished original observations. We are especially grateful to Dr. Gart Westerhout, scientific director, and Mrs. Brenda G. Corbin, librarian, of the US Naval Observatory, Washington; to Professor Owen Gingerich and Mrs. Barbara L. Welther of the Smithsonian Astrophysical Observatory; to Dr. Martha Hazen of the Harvard College Observatory; to Drs. Nils Hansson and Gösta Lyngå of Lund Observatory, who tracked down the Dunér observations; and to Professor Martin Schwarzschild, of Princeton University Observatory, who sent us copies of C. A. Young's observing records. We also received helpful assistance and contributions from Dr. M. Breger, director, Vienna Observatory; Dr. B. Westerlund, director, Uppsala Observatory; Dr. D. W. Dewhirst, Institute of Astronomy, University of Cambridge; Dr. C. Moss and Fr. J. Cassanovas, Vatican Observatory; Fr. F. Turner, librarian-archivist, and Mr. F. O'Neill, Stonyhurst College Observatory; Dr. S, Mancuso, Capodimonte Observatory, Naples; Drs. J. Heidmann and J. Lévy, Paris-Meudon Observatory; and Mrs. A. M. de Narbonne, curator of the Paris Observatory Museum; who searched for us the archives and libraries of their respective institutions.

[13] Numerous measurements of star a relative to N over more than a century (1838–1958) show it to have negligible proper motion.

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