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INFRARED LIGHT CURVES OF TYPE I SUPERNOVAE, II. LATE STAGES.

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ABSTRACT

Infrared light curves of three Type I supernovae obtained by Elias *et al.* are extended to approximately 1 year after maximum light. The light curves and colors show no evidence for the development of an infrared excess. The very red $J-H$ color observed roughly 100 days after maximum becomes bluer, probably indicating decreased absorption at 1.2 μm.

Subject headings: infrared: sources — stars: supernovae.

I. INTRODUCTION

During 1980–1981 three Type I supernovae erupted in the nearby galaxies NGC 1316 and NGC 4536. These have been extensively observed in the near-infrared (*JHKL*) by Elias *et al.* (1981, henceforth Paper I) and by others (see references in Paper I). The resulting data indicate that composite infrared light curves can be formed with small scatter out to times at least 100 days past maximum ($t=100$). The J (1.25 μm) light curve shows a curious double maximum and large amplitude. Since the flux at this wavelength is depressed, this behavior is attributed to a strong and variable absorption in this filter (Paper I). This hypothesis requires that the very red $J-H$ color (~ 1.6) observed near $t=100$ days should gradually decrease as the supernova envelope becomes transparent. Additional observations were made to see whether $J-H$ becomes bluer at late stages and to study the overall behavior of the infrared light curve.

II. OBSERVATIONS

Observations of the three supernovae (SN 1980n and 1981d in NGC 1316, and SN 1981b in NGC 4536) were made in 1981 July and December. To aid in locating the faint NGC 1316 supernovae, their positions were measured from a 4 m prime focus plate (SN 1980n only) and a Curtis Schmidt plate (both supernovae); the results are listed in Table 1, together with the position of the nucleus of the galaxy from Schweizer (1981). The offsets from the nucleus are at least as accurate as the positions and should be of value in searching for the supernova remnants at radio wavelengths.

The infrared observations were all made with the CTIO 4 m telescope, and reduced in the same way as for Paper I. The corrections for flux from the underlying galaxies for these measurements were comparable in size to the uncorrected observations themselves; for this reason both the *corrected* supernova magnitudes and the corrections are given in Table 2. The observations were all made chopping 10″ in declination with either a 7″.1 or 5″.3 beam; the corrections listed are appropriate for the 7″.1 beam and are 0.62 mag less for the 5″.3 beam. The quoted uncertainties in the corrections were derived by averaging measurements of the galaxy adjacent to each supernova; this assumes that there is little structure in the galaxy on the scale of ~ 10″ at the position of the supernova. For NGC 1316 this seems to be the case, judging from the scatter in the measurements and the visual appearance of the galaxy (e.g., Schweizer 1980). For NGC 4536, the correction measurements show greater scatter, and it is possible that the true uncertainties are near 30%. This would have the effect of increasing the uncertainties for the mean corrected SN 1981b magnitudes by less than 20% and would not affect the conclusions of this paper.

TABLE 1
FORNAX POSITIONS

Object	α(1950)	δ(1950)
NGC 1316[a] ...	$3^h20^m47^s.21 \pm 0^s.02$	−37°23′08″.2 ± 0″.2
SN 1980n......	3 21 05.88 ± 0.02	−37 23 27.9 ± 0.2
SN 1981d......	3 20 43.97 ± 0.02	−37 24 36.2 ± 0.3

[a]Position of nucleus from Schweizer 1981.

III. DISCUSSION

The H (1.6 μm) light curve (Fig. 1) shows a reduced rate of decline after roughly $t=110$. The dashed line segments represent plausible fits to the light curve, though it is not well determined beyond $t=140$. Comparison with photographic light curves (e.g., Barbon 1980) or sparser bolometric light curves (Kirshner 1980)

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TABLE 2

SUPERNOVA PHOTOMETRY

SUPERNOVA	(JD – 2,444,000)	INFRARED MAGNITUDES[a] J	H	K	PHASE[b] (days)
NGC 4536[c]					
= SN 1981b	807.5	18.85(54)	16.78(14)	16.48(14)	139.3
	808.5[d]	18.38(38)	17.00(11)	16.50(10)	140.3
	809.5[d]	18.37(15)	16.84(8)	...	141.3
	Mean	18.47(14)	16.87(7)	16.50(9)	140.3
NGC 1316 #1[e]					
= SN 1980n	808.9	...	18.74(36)	...	228.2
	809.9	...	19.93(132)	...	229.2
	Mean	...	19.07(39)	...	228.7
	953.7	...	> 18.71(3σ)	...	373.0
NGC 1316 #2[f]					
= SN 1981d	953.7	19.25(21)	18.76(20)	...	280.7

[a] Magnitudes corrected for galaxy contamination. Uncertainties in percent are given in parentheses after the individual magnitudes. Observations were with a 7″.1 beam except as noted.

[b] Time after maximum, as defined in Paper I.

[c] Corrections, which were added to observed magnitudes, are $J = 19.25(15)$, $H = 18.40(25)$, and $K = 18.20(25)$. See text.

[d] Observed with 5″.3 beam.

[e] Correction, which was subtracted from observed magnitude, is $H = 21.95(211)$.

[f] Corrections, which were added to observed magnitudes, are $J = 19.75(13)$ and $H = 19.25(15)$.

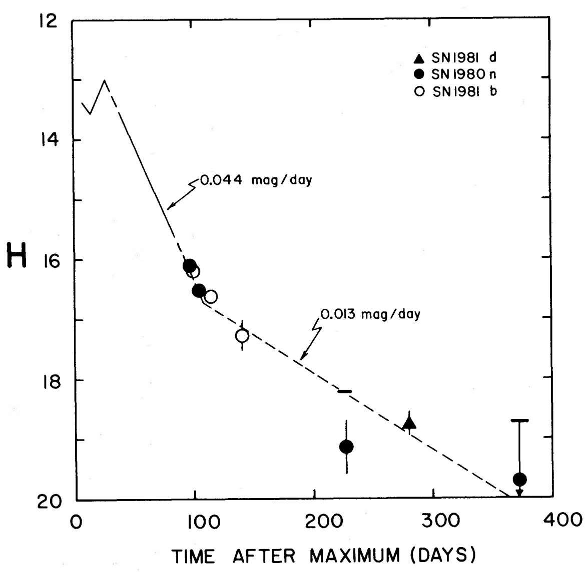

FIG. 1.— H magnitudes of Type I supernovae. The light curve prior to $t = 80$ is shown by a line; the individual observations are not shown (the dashed portions are poorly defined). Individual observations after $t = 80$ are plotted and are either from Paper I or Table 2 here. The SN 1981b data have been shifted by +0.4 mag to correct for the difference in distances between NGC 1316 and NGC 4536 (see Paper I).

shows that the rate of decline after $t \sim 100$ is similar at all wavelengths and that the visual minus infrared colors are not particularly red. (Data from Tsvetkov (1982) imply $V - H$ of ~ -0.4 at $t = 100$.) There is little evidence at H for the kind of dispersion seen in photographic light curves (cf. Barbon 1980; Branch 1982), though the sample contains only three objects. The K (2.2 μm) light curve (not shown) is probably similar, though there are no data beyond $t = 140$. There is no evidence of excess emission at K prior to $t = 150$ or at H prior to $t = 300$. The J (1.2 μm) light curve is also not well defined, but is probably characterized by a steeper initial decline to $t \sim 120$ followed by a shallower late decline. This is reflected in the $J - H$ color curve (Fig. 2); the $J - H$ color apparently gets bluer some time after $t \sim 120$. The data are not very accurate, and more are needed to better define the behavior. If real, it supports the suggestion made in Paper I that there is strong absorption at 1.2 μm, since as the expanding supernova envelopes become transparent, the absorption feature must eventually disappear.

Comparison with the data for Type II supernovae shows that the appearance of excess emission at H, K, and L in these objects may occur later than $t = 150$ (Merrill 1980; Telesco *et al.* 1981; Allen and Bode 1982), when there are only J and H data in Table 2. The H observations in Table 2 are roughly 3 mag fainter than those of similarly distant Type II supernovae at similar times.

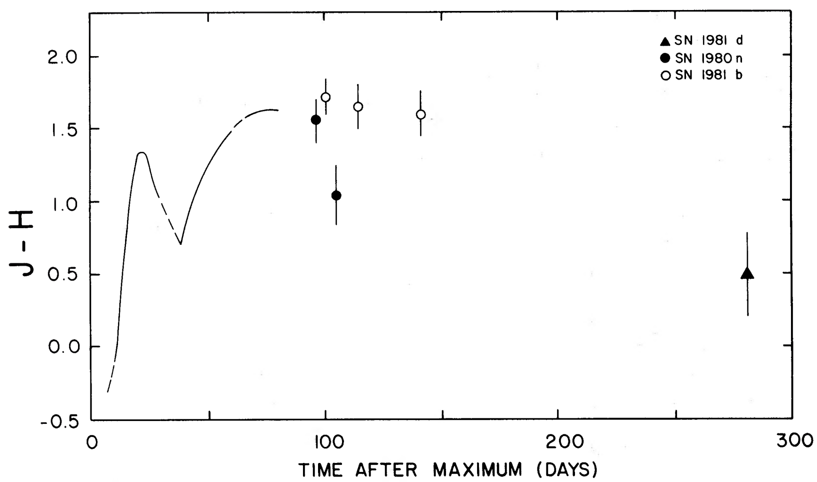

FIG. 2.—$J - H$ colors of Type I supernovae, as in Fig. 1

The results presented in Table 2 represent practical limits for infrared observations with present-day infrared equipment; these are set as much by the difficulty in determining accurate corrections for the underlying galaxy as by photon noise from emission from sky and telescope. Additional observations of similar quality would help somewhat in defining the light curve to $t \sim 300$, but useful observations at later points on the light curve will require either major instrumental developments or a supernova within a few megaparsecs.

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