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OPTICAL LIGHT CURVES OF THE TYPE Ia SUPERNOVAE SN 1990N AND SN 1991T

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ABSTRACT

We present *UBVRI* light curves for the bright Type Ia supernovae SN 1990N in NGC 4639 and SN 1991T in NGC 4527, based on photometry gathered in the course of the Calán/Tololo supernova program. Both objects have well-sampled light curves starting several days before maximum light and spanning well through the exponential tail. These data supersede the preliminary photometry published by Leibundgut et al. and Phillips et al. The host galaxies for these supernovae have (or will have) accurate distances based on the Cepheid period-luminosity relationship. The photometric data in this paper provide template curves for the study of the general population of Type Ia supernovae and accurate photometric indices, needed for the Cepheid-supernova distance scale.
Key words: galaxies: distances and redshifts — supernovae: individual (1990N, 1991T)

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1. INTRODUCTION

It is now clear that Type Ia supernovae are not a homogenous class of objects. One can see differences in spectral features at specific epochs (Bertola 1964; Branch 1987; Phillips et al. 1987; Harkness & Wheeler 1990; Nugent et al. 1995; Filippenko 1997) and in the overall morphology of the light curves (Phillips et al. 1987; Phillips 1993; Suntzeff 1996), which had long been suspected by earlier workers (Barbon, Ciatti, & Rosino 1973; Rust 1974; Pskovskii 1977; Branch 1981; Pskovskii 1984). The modern data have shown us, however, that the class of Type Ia supernovae can still be used to provide accurate *relative* distances by applying correction factors to the observed luminosity that are a simple function of the evolution of the light curve near maximum light (Phillips 1993; Hamuy et al. 1995; Riess, Press, & Kirshner 1995). The simple proof that these techniques work is the reduction in the magnitude scatter of a Hubble diagram for distant supernovae, where the scatter reduces from about 0.4 mag to 0.14 mag (Hamuy et al. 1996b; Riess, Press, & Kirshner 1996).

To use the very high accuracy of the zero point of the distant supernova Hubble diagram to measure an accurate *absolute* distance scale requires the direct measurements of the distances to a number of nearby galaxies that have had well-observed Type Ia supernovae (SNe). One of the most accurate methods to measure absolute distances to nearby galaxies is the use of the Cepheid period-magnitude relationship calibrated relative to the Large Magellanic Cloud (Madore & Freedman 1991). With an independent measurement of the distance to the LMC, the observed Hubble diagram of distant supernovae will directly yield the Hubble constant. The nearby calibrating galaxies must have three rather trivial properties: the galaxy must be young enough to form classical Cepheids, the galaxy must have hosted a reasonably "normal" Type Ia supernova, and the supernova light curve must have been reasonably well measured.

There are only a handful of such supernova host galaxies within the light grasp of the *Hubble Space Telescope* (*HST*), where the limiting distance modulus for measuring Cepheid light curves is about 32.0. Six supernovae, SNe 1895B, 1937C, 1960F, 1972E, 1981B, and 1990N, have been calibrated to date by Saha, Sandage, and collaborators (see Saha et al. 1996 for the most recent paper in this series).

We have pointed out (Hamuy et al. 1996b) that a few of the nearby supernovae are not ideal as calibrators. The light curves for SNe 1895B and 1960F are very poor, with ill-defined maxima. SN 1937C was well observed, but the transformation from the 60 year–old films to modern photometric bandpasses, while carefully calibrated (Pierce & Jacoby 1995), remains controversial in some circles (Schaefer 1996; rebuttal in Jacoby & Pierce 1996). Both 1937C and 1972E clearly had "slower" evolution near maximum light, which we have shown is indicative of intrinsically brighter supernovae (Hamuy et al. 1996a); however, this latter point has been contested (Tammann & Sandage 1995; Sandage et al. 1996). SN 1989B had very high reddening [$E(B-V) \sim 0.4$; Wells et al. 1994]. Only SNe 1981B and 1990N have evidently both uncontroversial light curves and Cepheid distances.

If we relax the requirement that the Cepheids must be measured in the *same* galaxy as the supernova and rely on group or cluster associations between galaxies, a number of other calibrators become available. Cepheid distances to NGC 3368 (M96) (Tanvir et al. 1995) and NGC 3351 (Graham et al. 1997) have been measured with *HST* data. Sandage et al. (1996) associate the M96 Group with a larger Leo Group (also called the Leo I cloud), which includes the compact M66 (Leo Triplet) Group. However, M66, which hosted SN 1989B, is some 8° away from the Cepheid host galaxies, and one must worry that the whole Leo Group is at the same distance. *HST* observations to determine a Cepheid distance to M66 are planned for *HST* Cycle 7 by Saha, Sandage, and collaborators. There have also been two well-studied Type Ia supernovae in the Fornax Cluster: SN 1980N (in NGC 1316) and SN 1992A (in NGC 1380). Silbermann et al. (1996) have measured a Cepheid distance to the peculiar spiral NGC 1365, thought to be a member of Fornax. Once again, the physical association of the supernova host galaxy and the Cepheid host galaxy is a point of some controversy. Such ambiguities lead us to prefer Type Ia supernova absolute magnitude calibrations based on galaxies that have both primary calibrators, such as Cepheids and supernova.

SN 1990N was discovered significantly before maximum in the SBb(r) galaxy NGC 4639 by E. Thouvenot at the Observatory of the Côte d'Azur on 1990 June 22 (Maury 1990; all dates referenced as UT). Pollas (1990) measured an astrometric position for this supernova of (R.A., decl., equinox) = ($15^h18^m52\overset{s}{.}92$, $-7°11'43\overset{''}{.}2$, B1950.0). Kirshner & Leibundgut (1990) classified it as a Type Ia supernova on the basis of a spectrum obtained on 1990 June 26. Leibundgut et al. (1991) presented preliminary light curves based on Cerro Tololo Inter-American Observatory (CTIO) CCD data (which are reanalyzed in the present paper). Spectral modeling has been published by Jeffery et al. (1992), Shigeyama et al. (1992), Yamaoka et al. (1992), and Fisher et al. (1997). Recently, Sandage et al. (1996) and Saha et al. (1996) have obtained the distance to the parent galaxy by measuring the periods and magnitudes of 20 Cepheid variable stars with *HST*. This object is therefore a key template objects in establishing the value of H_0 based on the Cepheid-supernova distance scale.

SN 1991T has been one of the most extensively studied Type Ia supernovae. It was discovered well before maximum in the Sb(s) II galaxy NGC 4527 by S. Knight and independent observers (Waagen et al. 1991) on 1991 April 13. An astrometric position for this supernova by R. H. McNaught is given in the previous reference as (R.A., decl., equinox) = ($12^h31^m36\overset{s}{.}91$, $+2°56'28\overset{''}{.}3$, J2000.0).

Early optical spectral observations reported by La Franca & Goldschmidt (1991), Kirshner (1991), and Phillips & Hamuy (1991) showed that SN 1991T was a peculiar Type Ia event, which motivated a number of theoretical studies to model the spectral evolution (Jeffery et al. 1992; Ruiz-Lapuente et al. 1992; Spyromilio et al. 1992; Yamaoka et al. 1992; Mazzali, Danziger, & Turatto 1995; Meikle et al. 1996). Optical photometry has been published by Phillips et al. (1992), Ford et al. (1993), and Schmidt et al. (1994) showing that SN 1991T had a very slow rate of evolution through maximum. Because of the excellent temporal coverage of the light curve, this supernova has been used as a template example of a slow supernova (Hamuy et al. 1996c; Riess et al. 1996). It is expected that the Saha and Sandage group will obtain a Cepheid distance to NGC 4527 using data taken with *HST* in Cycle 7.

When accurate modern light curves for several nearby supernovae became available some years ago, subtle differences between Type Ia supernova light curves became apparent. CCD photometry showed that there is a real spread in the peak luminosity and that some of the objects evolve through maximum light more slowly than others. Phillips (1993) presented evidence that the rate of the decline after maximum is correlated with the luminosity at maximum and that more luminous objects have a slower decline rates. Hamuy et al. (1995), Riess et al. (1995), Hamuy et al. (1996b), and Riess et al. (1996) have found that the scatter in the Hubble diagram of Type Ia supernovae decreases significantly when corrections for the peak luminosity–decline rate relation are introduced. Tammann & Sandage (1995) argued that when samples are restricted to "normal" objects (by eliminating events like SN 1991T) there is no need to correct for a peak luminosity–decline rate effect. However, the Hamuy studies find that by ignoring this effect, the estimate of the Hubble constant can be biased too low by up to 15%.

The intent of this paper is to present accurate light curves of the two nearby supernovae, SN 1990N and SN 1991T, that are important calibrators of the distance scale. We have already used these light curves in our work on the Hubble constant (Hamuy et al. 1996b). In § 2 of this paper, we present the observations and reduction of the optical photometric data obtained at CTIO. The light curves, as well as color curves, for both supernovae are shown in § 3. A final discussion is found in § 4.

2. OBSERVATIONS

The optical observations of SNe 1990N and 1991T were obtained using the 0.9 m and the Blanco 4 m telescopes at CTIO. SN 1990N was observed from 1990 June to 1992 March, and SN 1991T was observed from 1991 April to 1992 June. The observations were made using Texas Instruments and Tektronix CCDs (except for the night of 1990 March 19, when a Thomson detector was used) and facility $UBV(RI)_{KC}$ filters in the Johnson-Kron-Cousins photometric system (Johnson 1963; Kron 1953; Cousins 1976). The observation logs are given in Tables 1 and 2. The detector name, listed in the final column of these two tables, combines the manufacturer name and a running number assigned by the CTIO CCD lab. We have assumed that each different CCD listed in this table (along with the filter set) has a unique set of color terms that must be derived from observations.

We made observations of the supernovae under varied photometric conditions, including very nonphotometric weather with cloud extinction up to a few magnitudes. It is well established (Serkowski 1970; Walker et al. 1971; Olsen 1983) that clouds are quite gray, which allows us to use local standards (in the same CCD frame as the supernova) and averaged color terms for a specific CCD measured on photometric nights.

For accurate photometry on nonphotometric nights, it is necessary to define a precise local photometric sequence of stars. We measured photometric sequences on 13 photometric nights in the CCD field around NGC 4639 and NGC 4527 referenced to Landolt and Graham standards stars (Landolt 1972; Graham 1982; Landolt 1992). Extinction coefficients, color terms, and zero points for the transformations to the standard $UBV(RI)_{KC}$ system were derived for each night following the method described by Harris, Fitzgerald, & Reed (1981). Typical values of the extinction coefficients were $k_U = 0.50$, $k_B = 0.32$, $k_V = 0.20$, $k_R = 0.14$, and $k_I = 0.08$, in units of mag airmass^{-1}.[10] We measured $UBV(RI)_{KC}$ sequences for a total of 15 stars for SN 1990N and nine stars for SN 1991T using digital aperture photometry with an aperture diameter of 14″. The photometric sequences are identified in Figures 1 and 2, and the photometry is given in Tables 3 and 4. In these tables we list the number of observing nights (n) and the total number of observations (m).

Star 2 in our local sequence around SN 1991T is also a sequence star (number 2) listed by Ford et al. (1993). The magnitude differences for this star in the sense of this study *minus* Ford et al.'s are $\Delta(VRI) = (0.00, -0.02, -0.03)$. For the three SN 1991T local standards in common with Schmidt et al. (1994), we find the mean differences in the sense of this study *minus* that of Schmidt et al. (1994) are $\Delta(BVRI) = (-0.03 \pm 0.01, \quad -0.04 \pm 0.01, \quad -0.02 \pm 0.02, +0.12 \pm 0.08)$, where the errors quoted are the mean errors. These mean differences are consistent with the photometric errors quoted in Schmidt et al. (1994), which dominate the comparison of the two magnitude systems. As a result of the larger number of measurements on independent photometric nights, we are confident that sequences given in Tables 3 and 4 are the most accurate available.

To determine the supernova magnitudes, we subtracted late-time images of the parent galaxies at the location of the supernovae using the technique described by Hamuy et al. (1994). For these subtractions, deep "master images" of NGC 4639 and NGC 4527 were obtained at the beginning of 1994, which corresponds to 1300 and 1010 days after maximum light for SNe 1990N and 1991T, respectively. A simple extrapolation of the late-time decline rates (see the γ-parameter in Table 8 below) to these dates yields B magnitudes of ~ 33 (SN 1990N) and ~ 28 (SN 1991T). However, there are two factors that could make the late-time magnitudes in the master images significantly brighter than this extrapolation.

The first factor is the presence of minor radioactive nuclides and the efficiency of positron energy deposition from the radioactive decays. A Type Ia explosion is predicted to synthesize about 0.5 $M_\odot$ of ^{56}Ni and smaller amounts of ^{56}Co, ^{57}Co, ^{44}Ti, and ^{22}Na (see model W7 in Nomoto, Thielemann, & Yokoi 1994). Woosley, Pinot, & Hartmann (1989) provide energy deposition rates for these nuclides. A complication arises when predicting the late-time light curve after day 500 in how to handle the energy deposition from the positron production (Arnett 1979). The positrons can add energy into the supernova nebula from both their kinetic energies and annihilations. The efficiency of this process is poorly understood in the low-density environment of the supernova nebula at late time. If we make the rather extreme assumption of complete kinetic energy deposition and positron annihilation into gamma rays, we can use the deposition rates given by Woosley et al. (1989) and the model W7 abundances by Nomoto et al. (1994) to predict upper limits to the supernova luminosity at late time. The effect of full energy deposition from positrons and the existence of long-lived radioactive nuclides such as ^{44}Ti and ^{22}Na tends to flatten out the light curve past day 1000.

[10] These extinction values are higher than normal because of the effects of the Mount Pinatubo eruption that occurred on JD 2,448,422 (see Grothues & Gochermann 1992).

TABLE 1

OBSERVATION LOG FOR SN 1990N

Date (UT)	Telescope	Observers	Filters	Detector
1990 Jun 29	4.0 m	M. N.	*UBVRI*	TI2
1990 Jul 3.........	0.91 m	D. M. R., E. S.	*BVR*	TEK4
1990 Jul 4.........	0.91 m	D. M. R., E. S.	*BVR*	TEK4
1990 Jul 4.........	0.91 m	N. B. S.	*BVRI*	TEK4
1990 Jul 12	0.91 m	L. A. W.	*UBVRI*	TEK4
1990 Jul 19	0.91 m	N. D. T., R. M. R.	*UBVRI*	TI2
1990 Jul 20	0.91 m	N. D. T., R. M. R.	*UBVRI*	TI2
1990 Jul 21	0.91 m	N. D. T., R. M. R.	*UBVRI*	TI2
1990 Jul 22	0.91 m	N. D. T., R. M. R.	*UBVRI*	TI2
1990 Jul 25	0.91 m	T. B. W.	*BVRI*	TEK4
1990 Jul 26	0.91 m	T. B. W.	*BVRI*	TEK4
1990 Aug 1	0.91 m	N. B. S.	*UBVRI*	TI3
1990 Aug 21	0.91 m	J. H. E.	*BVRI*	TI3
1990 Dec 28	0.91 m	F. K. B.	*BVRI*	TI3
1991 Jan 16.......	0.91 m	L. G.	*BVRI*	TI3
1991 Feb 5........	0.91 m	M. N.	*BVRI*	TI2
1991 Feb 12	4.0 m	M. N.	*UBVRI*	TEK1
1991 Feb 20	0.91 m	M. N.	*BVRI*	TEK4
1991 Mar 7	0.91 m	N. B. S.	*BVRI*	TI3
1991 Mar 19......	0.91 m	J. R.	*VI*	Thomson
1991 Mar 20......	0.91 m	N. B. S.	*BVRI*	TI3
1991 Apr 1........	0.91 m	A. P. S. C.	*UBVRI*	TEK1
1991 Apr 7........	0.91 m	P. U.	*BVRI*	TEK2
1991 Apr 9........	4.0 m	M. N.	*BVRI*	TEK1
1991 Jun 7........	4.0 m	M. N.	*BVRI*	TI2
1991 Jun 13	0.91 m	M. N.	*BVR*	TEK4
1991 Jul 23	0.91 m	A. D.	*BV*	TEK2
1992 Mar 6	4.0 m	N. B. S., M. N.	*VR*	TEK2

Using a column depth of 400 g cm^{-2} at $t = 10^6$ s as suggested by Woosley et al. (1989) for a Type Ia supernova, we predict V magnitudes of 29.6 and 25.4 for SNe 1990N and 1991T, respectively, at the epoch of the master image. For no positron energy deposition, the predicted magnitudes are about 3 mag fainter. In either case, the predicted magnitudes in the master images are so faint as to have no effect on the measured photometry. However, if there is significant overproduction of ^{57}Co or ^{44}Ti relative to model W7, the late-time magnitudes could be much brighter and affect the magnitudes measured by image subtraction.

The second factor that could affect the magnitudes measured from the subtracted images is the presence of a light echo. In the late-time images of SN 1991T, the location of the supernova has been found to be contaminated by a faint echo of SN 1991T at maximum light (Schmidt et al. 1994). We will return to this minor complication in § 3.

We measured differential photometry of the supernovae on each CCD frame, using aperture photometry when the supernova was bright and using the point-spread function (PSF) fitting program DAOPHOT (Stetson 1987) when the supernova was faint. Averaged color terms chosen to match the CCD/filter setup of instruments for each observing night were adopted from a database of coefficients at CTIO. For SN 1991T near maximum, our CCD exposures were very short and the local standards were poorly exposed. In this case we used the sharp core of NGC 4527 as a BV "standard" for the nights of 1991 April 26, 28, 29, and 30 and May 1. An aperture radius of 2."7 was chosen to maximize the signal-to-noise ratio for the photometry of the core. The core photometry is listed in Table 4.

Besides the error given by the Poisson statistics of the number of counts in the supernova aperture or PSF, σ_{phot}, there are other error sources, such as those due to the transformation of the instrumental magnitudes into the standard system and CCD flat-fielding. To get a sense of the magnitude of these errors, we selected many frames with a sufficient number of bright stars (with negligible σ_{phot}). For each frame, we calculated the standard deviation of the difference between a given measurement and the standard magnitudes listed in Tables 3 and 4. This standard deviation (σ_{rms}) is an empirical estimate of the average error in a *single* observation of a stellar object in any CCD frame when referenced to the local photometric sequence. The measured standard deviations σ_{rms} were 0.026, 0.017, 0.017, 0.015, and 0.017 mag in $UBVRI$, respectively. The value of σ_{rms} derived for both supernovae in each filter agreed within 0.002 mag.

The final error in the individual magnitudes of the supernovae was calculated as the quadratic sum of the empirical error in a single observation, σ_{rms}, and the photon statistical error, σ_{phot}. The error σ_{rms} was the dominant component of the errors in the early part of the photometry, while σ_{phot} became more important when the supernova dimmed.

3. RESULTS

3.1. *Light Curves*

We present $UBV(RI)_{KC}$ photometry for SNe 1990N and 1991T in Tables 5 and 6 and plot the data in Figures 3 and 4. To find the time and magnitude of maximum light for both supernovae, we fitted the data around the peak with a third-order polynomial. For SN 1990N the first observation was acquired 11 days before B_{max}, and the last observation was made 607 days after B_{max} in just the V band. The B maximum was reached on JD 2,448,082.7 ± 0.5, with $B_{max} = 12.76 \pm 0.03$ and a $B-V$ color of 0.03 mag. For SN 1991T the data begin 12 days before B_{max} and end 401 days after maximum. We derive $B_{max} = 11.70 \pm 0.02$ at JD 2,448,375.7 ± 0.5 with a $B-V$ color of 0.17. In Table 7, we summarize the maxima of the light curves in the different bands

TABLE 2

OBSERVATION LOG FOR SN 1991T

Date (UT)	Telescope	Observers	Filters	Detector
1991 Apr 17	0.91 m	J. H., P. G.	*BVR*	TEK4
1991 Apr 18	0.91 m	J. H., P. G.	*BVR*	TEK4
1991 Apr 19	0.91 m	R. A. S.	*UBVRI*	TI3
1991 Apr 20	0.91 m	J. A. B.	*BVR*	TI3
1991 Apr 26	0.91 m	R. A. S.	*BVRI*	TEK1
1991 Apr 27	0.91 m	R. A. S.	*UBVI*	TEK1
1991 Apr 28	0.91 m	L. A. W.	*UBVRI*	TI3
1991 Apr 29	0.91 m	L. A. W.	*UBVRI*	TI3
1991 Apr 30	0.91 m	L. A. W.	*UBVRI*	TI3
1991 May 1	0.91 m	L. A. W.	*UBVRI*	TEK4
1991 May 4	0.91 m	G. M. W.	*BVRI*	TEK4
1991 May 5	0.91 m	G. M. W.	*BVRI*	TEK4
1991 May 6	0.91 m	G. M. W.	*BVRI*	TEK4
1991 May 7	0.91 m	M. N.	*UBVRI*	TEK4
1991 May 9	4.0 m	M. N.	*BVRI*	TEK1
1991 May 10......	0.91 m	A. R. W.	*BVRI*	TI3
1991 May 12......	0.91 m	N. D. T.	*UBVRI*	TEK4
1991 May 14......	0.91 m	L. A. W.	*UBVRI*	TI3
1991 May 17......	0.91 m	L. G.	*UBVRI*	TI3
1991 May 19......	0.91 m	A. L.	*BV*	TI3
1991 May 29......	0.91 m	G. M. W.	*BVRI*	TEK2
1991 Jun 7	4.0 m	M. N.	*UBVRI*	TI2
1991 Jun 13.......	0.91 m	M. N.	*UBVRI*	TEK4
1991 Jun 24.......	0.91 m	R. A. S.	*UBVRI*	TEK2
1991 Jul 1	0.91 m	P. S.	*BVI*	TEK1
1991 Jul 2	0.91 m	R. A. S.	*BVRI*	TI3
1991 Jul 3	0.91 m	T. B. W.	*BVRI*	TI3
1991 Jul 5	0.91 m	M. N.	*UBVRI*	TI3
1991 Jul 8	0.91 m	E. S.	*BV*	TEK2
1991 Jul 22........	0.91 m	A. D.	*BVRI*	TEK2
1992 Jan 7	0.91 m	R. A. S.	*BVI*	TEK2
1992 Jan 8	0.91 m	R. A. S.	*BVI*	TEK2
1992 Feb 25	0.91 m	E. S.	*VI*	TEK1
1992 Mar 6	4.0 m	N. B. S., M. N.	*BVRI*	TEK1
1992 Mar 10......	0.91 m	M. H.	*BVRI*	TEK4
1992 Apr 8........	0.91 m	Y.-C. K.	*BVI*	TEK2
1992 Apr 19	0.91 m	R. A. S.	*BV*	TEK1
1992 Jun 4	0.91 m	L. A. W.	*UBVRI*	TEK4

for both supernovae. We find that the B maximum occurs before the V maximum; in particular, the time difference between the B and V maxima is 1.5 ± 0.7 days for SN 1990N and 2.6 ± 0.7 days for SN 1991T, in agreement with the result of Leibundgut (1988), who found a difference of 2.5 ± 0.5 days.

Comparisons of our BV photometry with previous data published for SNe 1990N and 1991T are shown in Figures 5 and 6. The agreement between the photometry presented in this paper and the results published by Leibundgut et al. (1991) for SN 1990N and Phillips et al. (1992) for SN 1991T is not surprising, since they are based on a subsample of the

TABLE 3

PHOTOMETRIC SEQUENCE FOR SN 1990N

Star[a]	n	m	V (m.e.) (mag)	$B-V$ (m.e.) (mag)	$V-R$ (m.e.) (mag)	$R-I$ (m.e.) (mag)	$U-B$ (m.e.) (mag)
1.......	5	9	15.728 (005)	1.076 (009)	0.646 (006)	0.512 (011)	1.002 (026)
2.......	5	8	17.810 (003)	0.659 (007)	0.414 (004)	0.457 (009)	0.013 (012)
3.......	7	13	18.514 (004)	0.702 (005)	0.453 (005)	0.457 (006)	0.013 (021)
4.......	6	12	17.118 (004)	0.623 (006)	0.379 (005)	0.362 (006)	0.074 (009)
5.......	7	13	18.846 (005)	0.730 (007)	0.435 (006)	0.408 (009)	0.280 (033)
6.......	7	13	18.622 (005)	0.519 (008)	0.333 (006)	0.362 (009)	−0.086 (024)
7.......	6	12	17.707 (003)	0.735 (006)	0.414 (004)	0.402 (005)	0.068 (018)
8.......	3	6	17.626 (003)	1.468 (006)	0.940 (004)	0.933 (005)	1.256 (092)
9.......	7	12	19.543 (005)	0.479 (010)	0.377 (006)	0.466 (010)	−0.129 (021)
10......	7	12	19.573 (010)	0.863 (026)	0.539 (013)	0.705 (014)	−0.269 (074)
11......	5	9	16.580 (004)	0.615 (007)	0.385 (006)	0.351 (006)	0.040 (008)
12......	7	13	19.140 (007)	1.484 (023)	1.104 (013)	1.509 (014)	0.601 (066)
13......	5	9	18.467 (010)	1.285 (021)	0.860 (011)	0.871 (006)	0.941 (062)
14......	4	9	16.602 (005)	1.455 (007)	0.955 (009)	0.996 (009)	1.072 (031)
15......	3	6	13.392 (001)	0.607 (002)	0.356 (002)	0.341 (003)	0.031 (200)

[a] See Fig. 1.

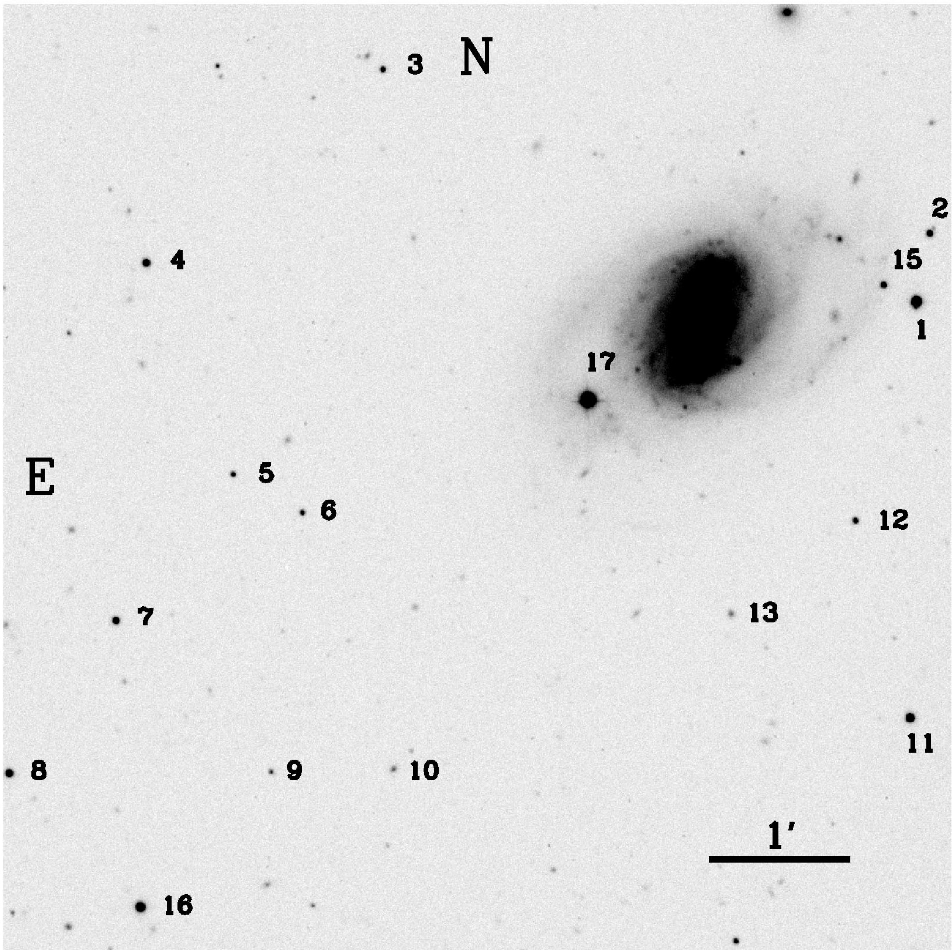

FIG. 1.—SN 1990N in NGC 4639. The local standards listed in Table 3 are marked. This *R* image was taken at the CTIO 0.9 m telescope on 1994 March 13. The field is 6$'.$8 on a side. Star 14 does not appear on this chart. It is located at ($12^h42^m47^s.0$, $+13°17'52''$, J2000.0) on the Digitized Sky Survey.

same optical data analyzed here. However, a small systematic difference between the different data sets is clear. Our photometry near maximum is generally dimmer, although the discrepancy is less than 0.1 mag for SN 1990N and even less for SN 1991T. The preliminary photometric results of these earlier papers, which were based on only a single night for the photometric calibration, should be ignored in preference of the photometric data given in Tables 5 and 6.

For SN 1991T there is independent photometry published by Ford et al. (1993), which we plot in Figure 6. If we interpolate our data to the dates of the Ford et al. (1993) data using a spline fit, we find the following differences in

TABLE 4

PHOTOMETRIC SEQUENCE FOR SN 1991T

Star[a]	*n*	*m*	*V* (m.e.) (mag)	*B*−*V* (m.e.) (mag)	*V*−*R* (m.e.) (mag)	*R*−*I* (m.e.) (mag)	*U*−*B* (m.e.) (mag)
1	6	10	15.172 (009)	0.908 (010)	0.523 (011)	0.483 (007)	0.647 (022)
2[b]	7	11	15.289 (009)	1.468 (011)	1.006 (012)	1.057 (011)	1.234 (033)
3	6	8	14.367 (014)	1.338 (026)	0.694 (014)	0.657 (006)	1.257 (053)
4	6	10	15.164 (006)	0.768 (006)	0.445 (008)	0.393 (009)	0.709 (019)
5	3	6	14.900 (007)	0.757 (007)	0.442 (009)	0.408 (006)	0.380 (005)
6	3	6	16.744 (005)	1.548 (009)	0.994 (009)	1.092 (014)	1.068 (008)
7[c].......	8	12	16.733 (003)	1.173 (009)	0.721 (006)	0.630 (010)	1.097 (011)
8[c].......	7	11	16.304 (003)	1.480 (006)	0.959 (007)	0.979 (006)	1.075 (042)
9[c].......	8	11	18.488 (010)	0.441 (011)	0.298 (012)	0.302 (017)	−0.241 (014)
G[d]......	4	7	14.297 (007)	1.290 (007)	0.837 (010)	0.885 (009)	0.241 (105)

[a] See Fig. 2.
[b] Star 2 is also star 2 in Ford et al. 1993.
[c] Stars 7, 8, and 9 are stars 2, 1, and 3 of Schmidt et al. 1994, respectively.
[d] G corresponds to the photometry of the NGC 4527 nucleus.

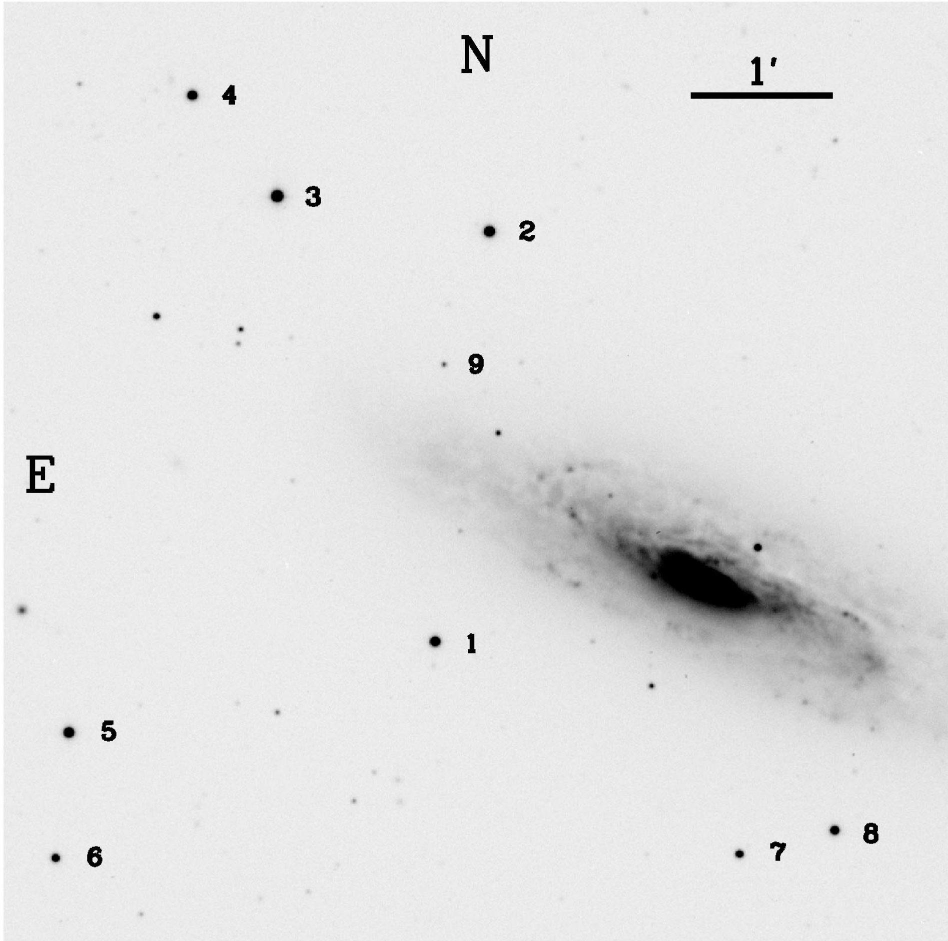

FIG. 2.—SN 1991T in NGC 4527. The local standards listed in Table 4 are marked. This *R* image was taken at the CTIO 0.9 m telescope on 1994 March 14. The field is 6′.8 on a side.

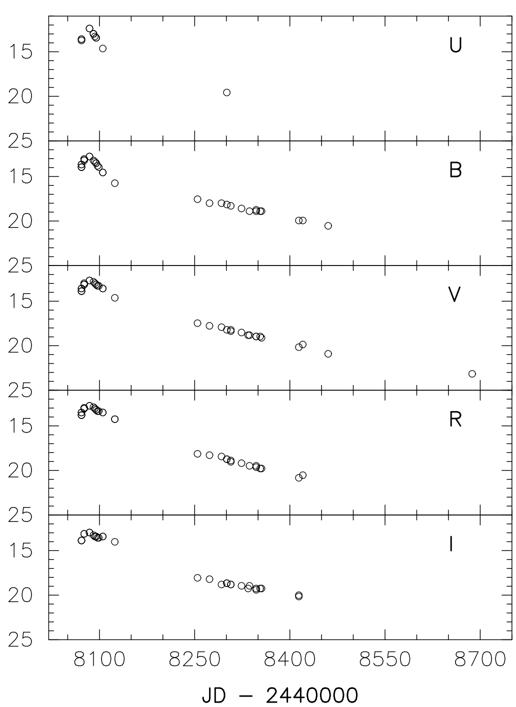

FIG. 3.—*UBVRI* light curves of SN 1990N

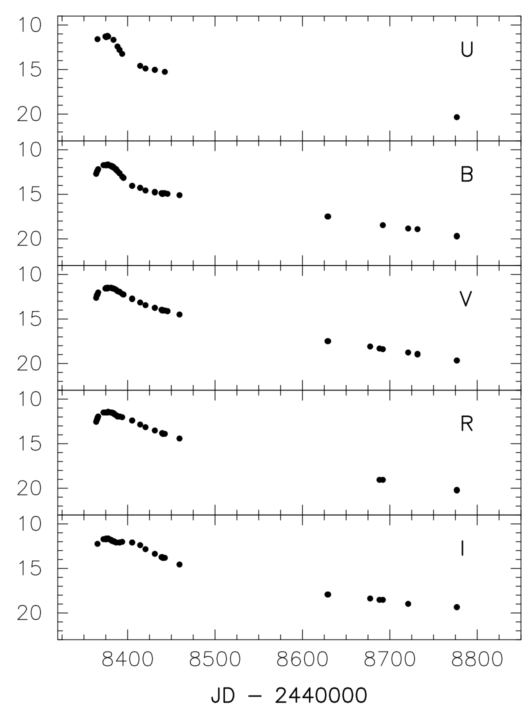

FIG. 4.—*UBVRI* light curves of SN 1991T

TABLE 5

SN 1990N Photometry

JD − 2,440,000	U (m.e.) (mag)	B (m.e.) (mag)	V (m.e.) (mag)	R (m.e.) (mag)	I (m.e.) (mag)
8,071.50	13.645 (026)	13.894 (017)	13.837 (017)	13.740 (013)	13.807 (015)
8,071.50	13.625 (026)	13.893 (017)	13.834 (017)	13.721 (013)	13.815 (016)
8,071.50	13.671 (026)	13.888 (017)	13.837 (017)	13.742 (013)	13.817 (016)
8,072.47	...	13.638 (017)	13.628 (017)	13.529 (013)	...
8,072.48	...	13.636 (017)	13.624 (017)	13.525 (013)	...
8,075.53	...	13.131 (017)	13.141 (017)	13.046 (013)	...
8,075.53	...	13.132 (017)	13.142 (017)	13.046 (013)	...
8,076.56	...	13.053 (017)	13.053 (017)	12.976 (013)	13.070 (015)
8,076.56	...	13.054 (017)	13.048 (017)	12.972 (013)	13.064 (015)
8,084.49	12.438 (026)	12.790 (017)	12.732 (017)	12.731 (013)	13.026 (015)
8,084.49	12.446 (026)	12.784 (017)	12.730 (017)	12.727 (013)	13.027 (015)
8,091.53	13.018 (026)	13.133 (017)	12.874 (017)	12.914 (013)	13.289 (016)
8,091.53	13.032 (026)	...	...	...	...
8,091.53	13.014 (026)	...	...	...	...
8,093.51	13.257 (026)	13.318 (017)	12.971 (017)	13.065 (013)	13.377 (016)
8,093.51	...	...	...	13.079 (013)	...
8,094.51	13.386 (026)	13.443 (017)	13.057 (017)	13.202 (013)	13.478 (016)
8,095.49	13.500 (026)	13.502 (017)	13.092 (017)	13.206 (013)	13.460 (016)
8,097.51	...	13.774 (017)	13.236 (017)	13.328 (013)	13.550 (015)
8,098.52	...	13.885 (017)	13.264 (017)	13.341 (013)	13.531 (015)
8,104.48	14.712 (026)	14.522 (017)	13.614 (017)	13.464 (013)	13.428 (015)
8,104.50	...	14.520 (017)	13.618 (017)	13.468 (013)	13.424 (015)
8,124.47	...	15.753 (022)	14.608 (018)	14.252 (021)	14.012 (018)
8,124.47	...	...	...	14.271 (018)	...
8,253.83	...	17.492 (019)	17.539 (018)	18.145 (019)	18.053 (045)
8,272.82	...	17.958 (018)	17.796 (018)	18.317 (020)	18.227 (041)
8,292.76	...	18.049 (043)	17.899 (044)	18.455 (086)	18.787 (218)
8,299.87	19.588 (059)	18.118 (018)	18.242 (018)	18.765 (017)	18.682 (034)
8,299.87	...	...	...	18.750 (027)	18.610 (040)
8,307.80	...	18.299 (023)	18.286 (023)	18.989 (047)	18.824 (046)
8,307.80	...	...	18.394 (025)	18.916 (021)	18.782 (043)
8,322.83	...	18.554 (027)	18.587 (029)	19.160 (047)	18.961 (050)
8,334.76	...	...	18.756 (027)	...	19.185 (088)
8,335.74	...	18.842 (021)	18.767 (023)	19.531 (038)	18.947 (061)
8,347.70	...	18.771 (076)[a]	18.941 (048)[a]	19.550 (057)[a]	19.378 (131)[a]
8,347.74	...	18.829 (092)[a]	18.900 (046)[a]	19.635 (073)[a]	19.318 (125)[a]
8,353.69	...	18.932 (028)	18.981 (026)	19.764 (041)	19.291 (066)
8,355.69	...	18.864 (018)	19.053 (019)	19.711 (018)	19.235 (025)
8,414.61	...	19.960 (035)[a]	20.114 (038)[a]	20.853 (042)[a]	20.107 (059)[a]
8,414.61	...	...	...	...	20.048 (070)[a]
8,420.54	...	19.888 (044)	19.931 (051)	20.527 (121)	...
8,459.51	...	20.541 (149)[a]	20.904 (231)[a]	...	...
8,687.82	...	...	23.198 (114)[a]	...	...

[a] PSF photometry.

the sense of this work *minus* Ford et al.: V, 0.08 ± 0.01; R, 0.04 ± 0.02; and I, 0.02 ± 0.02. The quoted errors are the errors in the mean based on the interpolation to the 12 dates in the Ford et al. study. A similar systematic offset in the V magnitude was noted by Ford et al. with respect to the Phillips et al. (1992) reductions of the SN 1991T data. These mean differences between careful photometric studies indicate the level in systematic errors that can be encountered even in bright supernova photometry.

It is now well established that there is not a unique light curve for all Type Ia supernovae. As was suggested by Pskovskii (1977) and Branch (1981), supernovae can be discriminated by the rate of decline after maximum. Pskovskii (1977, 1984) defined the parameter β as the characteristic decline rate during the fast-decline phase of the B supernova light curve and the parameter γ as the rate during the slow-decline phase (see Phillips et al. 1987 for an unambiguous description of these parameters). Phillips (1993) introduced the parameter Δm_{15}, defined as the decline in magnitude during the 15 days after B maximum. The evidence from nearby supernovae (Phillips 1993; Hamuy et al. 1996c) and the scatter in the observed Hubble diagram (Maza et al. 1994; Hamuy et al. 1995, 1996b) clearly show that the brighter supernovae decline more slowly (small Δm_{15}).

In Table 8, we list the evolutionary parameters of the B light curves for our two supernovae. We also list the values for the Leibundgut (1988) template B curve. This multicolor template, which was formed from a large number of supernova light curves, provides a useful fiducial light curve and can be considered a "typical" light curve that can be compared with other observations. We calculated the Pskovskii β- and γ-parameters for the B curves of SNe 1990N and 1991T by using a linear least-squares fit, with the data weighted using the photometric errors as quoted in Tables 5 and 6. The range of days used in the fitting for each supernova are indicated in Table 8.

Table 8 shows that both $\beta(B)$ and Δm_{15} are much smaller for SN 1991T than the values for the Leibundgut template.

TABLE 6

SN 1991T Photometry

JD − 2,440,000	U (m.e.) (mag)	B (m.e.) (mag)	V (m.e.) (mag)	R (m.e.) (mag)	I (m.e.) (mag)
8,363.77	...	12.712 (016)	12.618 (016)	12.526 (015)	...
8,364.76	...	12.449 (016)	12.362 (016)	12.299 (015)	...
8,365.66	11.610 (026)	12.362 (016)	12.256 (016)	12.134 (015)	12.215 (017)
8,365.65	...	...	...	12.159 (015)	...
8,366.67	...	12.152 (016)	12.061 (016)	11.971 (015)	...
8,372.70	...	11.748 (016)[b]	...	11.533 (015)	11.693 (017)
8,374.64	11.282 (026)[a]	11.719 (016)[b]	11.573 (016)[b]	11.511 (015)	11.690 (017)
8,374.64	11.304 (026)[a]	11.707 (016)[b]	11.560 (016)[b]	11.519 (015)	11.694 (017)
8,375.65	11.370 (026)[a]	11.715 (016)[b]	11.568 (016)[b]	11.529 (015)	11.689 (017)
8,375.65	11.270 (026)[a]	11.720 (016)[b]	11.537 (016)[b]	11.509 (015)	11.676 (017)
8,376.69	11.279 (026)[a]	11.696 (016)[b]	11.542 (016)[b]	11.474 (015)	...
8,376.69	11.233 (026)[a]	11.741 (016)[b]	11.527 (016)[b]	11.475 (015)	...
8,376.69	...	...	...	...	11.690 (017)
8,377.62	11.329 (026)[a]	11.694 (016)[b]	11.511 (016)[b]	11.435 (015)	11.664 (017)
8,377.62	...	11.711 (016)[b]	11.482 (016)[b]	11.435 (015)	11.665 (017)
8,380.70	...	11.832 (016)	11.525 (016)	11.466 (015)	11.788 (017)
8,380.69	...	...	11.529 (016)	11.479 (015)	11.805 (018)
8,381.60	...	11.836 (016)	11.535 (016)	11.518 (015)	11.847 (017)
8,381.60	...	11.857 (016)	...	11.501 (015)	11.846 (017)
8,382.67	...	11.912 (016)	11.577 (016)	11.565 (015)	11.915 (017)
8,382.68	...	11.919 (016)	11.575 (016)	11.552 (015)	11.917 (017)
8,383.58	11.652 (026)	11.959 (016)	11.605 (016)	11.589 (015)	11.966 (017)
8,383.58	...	11.971 (016)	11.583 (016)	11.585 (015)	11.967 (017)
8,385.63	...	12.137 (016)	11.643 (016)	11.730 (015)	12.051 (017)
8,385.62	...	...	...	11.729 (015)	12.049 (017)
8,386.55	...	12.248 (016)	11.764 (016)	11.811 (015)	12.087 (017)
8,386.55	...	12.208 (016)	...	...	...
8,388.57	12.381 (026)	12.408 (016)	11.873 (016)	11.917 (015)	...
8,390.50	12.750 (026)	12.603 (016)	11.974 (016)	11.982 (015)	12.076 (017)
8,390.50	12.778 (026)	12.600 (016)	11.971 (016)	11.976 (015)	12.062 (017)
8,393.62	13.222 (026)	12.965 (016)	12.150 (016)	12.029 (015)	12.022 (017)
8,395.55	...	13.131 (016)	12.223 (016)	...	...
8,395.56	...	13.149 (016)	12.247 (016)	...	...
8,405.59	...	14.071 (016)	12.731 (016)	12.378 (015)	12.098 (017)
8,405.59	...	14.071 (017)	12.735 (016)	12.379 (015)	12.111 (017)
8,414.62	14.610 (026)	14.302 (016)	13.123 (016)	12.820 (015)	12.421 (017)
8,414.62	...	14.307 (016)	...	...	...
8,420.47	14.862 (026)	14.556 (016)	13.423 (016)	13.102 (015)	12.819 (017)
8,431.49	15.032 (030)	14.770 (017)	13.744 (016)	13.527 (015)	13.386 (017)
8,431.49	15.070 (030)	14.746 (017)	13.754 (016)	...	...
8,438.50	...	14.863 (016)	13.936 (016)	...	13.712 (017)
8,439.47	...	14.931 (016)	13.986 (016)	13.830 (015)	13.738 (017)
8,439.47	...	14.919 (016)	14.018 (016)	13.824 (015)	13.749 (017)
8,440.46	...	14.897 (016)	14.059 (016)	13.859 (001)	13.821 (017)
8,440.46	...	14.917 (016)	14.058 (016)	13.872 (015)	13.790 (017)
8,442.48	15.265 (026)	14.888 (016)	14.045 (016)	13.888 (015)	13.778 (017)
8,445.46	...	...	14.139 (016)	...	...
8,445.47	...	14.934 (017)	14.143 (016)	...	...
8,459.49	...	15.115 (016)	14.476 (016)	14.407 (015)	14.538 (017)
8,628.83	...	17.496 (019)	17.484 (018)	...	17.939 (040)
8,629.83	...	17.513 (018)	17.475 (018)	...	17.951 (046)
8,677.78	...	...	18.116 (022)	...	18.367 (045)
8,687.85	...	...	18.343 (017)	19.086 (022)	18.489 (026)
8,691.78	...	18.445 (018)[a]	18.357 (019)[a]	19.080 (025)[a]	18.489 (031)[a]
8,720.77	...	18.834 (023)[a]	18.765 (022)[a]	...	18.952 (034)[a]
8,731.63	...	18.916 (078)[a]	18.947 (047)[a]	...	...
8,731.62	...	...	19.010 (052)[a]	...	...
8,776.53	20.346 (250)[a]	19.654 (078)[a]	19.662 (057)[a]	20.271 (102)[a]	19.374 (119)[a]
8,776.54	...	19.773 (097)[a]	19.684 (063)[a]	20.162 (097)[a]	19.359 (113)[a]

[a] PSF photometry.
[b] Photometry calibrated using the core of NGC 4527.

Phillips (1993) has shown that this "slow" supernova was intrinsically very bright. In fact, SN 1991T is one of the slowest supernovae ever found and has been used as a representative template for slow events (Hamuy et al. 1995, 1996c). SN 1990N, on the other hand, is quite similar to the Leibundgut template and is therefore similar to the typical Type Ia event.

In Figures 7 and 8, we plot the first 120 days of *BV* photometry for the two supernovae along with the Leibundgut templates. The *BV* templates have been shifted to

TABLE 7

PEAK PHOTOMETRIC MAGNITUDES

Filter	Magnitude	JD − 2,440,000
SN 1990N:		
U	12.38 ± 0.02	8,081.8 ± 1.0
B	12.76 ± 0.03	8,082.7 ± 0.5
V	12.70 ± 0.02	8,084.2 ± 0.5
R	12.69 ± 0.02	8,082.9 ± 0.5
I	12.94 ± 0.02	8,080.7 ± 1.0
SN 1991T:		
U	11.26 ± 0.02	8,374.0 ± 1.0
B	11.70 ± 0.02	8,375.7 ± 0.5
V	11.51 ± 0.02	8,378.3 ± 0.5
R	11.46 ± 0.02	8,377.1 ± 0.5
I	11.67 ± 0.02	8,375.3 ± 1.0

match the epoch of *B* maxima and the peak magnitudes given in Table 7 (with the appropriate time delay between *B* and *V* maximum given above). The results given in the preceding paragraph can now be clearly seen in these figures. SN 1990N follows the template closely while SN 1991T declines from maximum light more slowly. SN 1991T also begins its exponential decline significantly earlier and remains at higher relative brightness when compared with the template. Visually, the "knee" in the light curve around 30 days past maximum occurs earlier in this supernova. SN 1991T also rises to maximum light more slowly than SN 1990N.

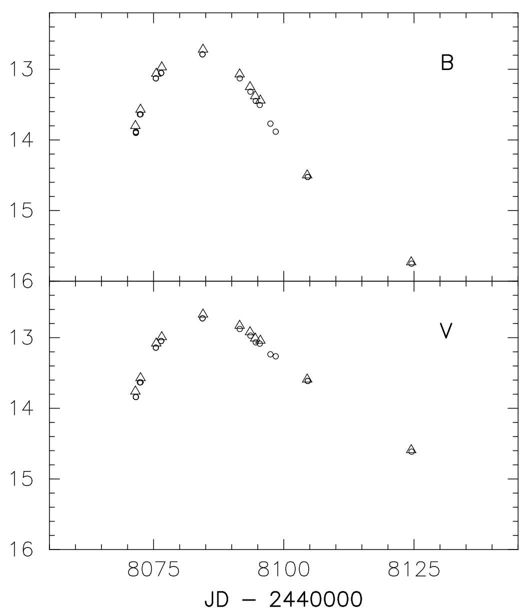

FIG. 5.—Comparison of the *B* and *V* photometry of SN 1990N given in this paper (*circles*) with the preliminary photometric reductions of the CTIO data by Leibundgut et al. (1991) (*triangles*).

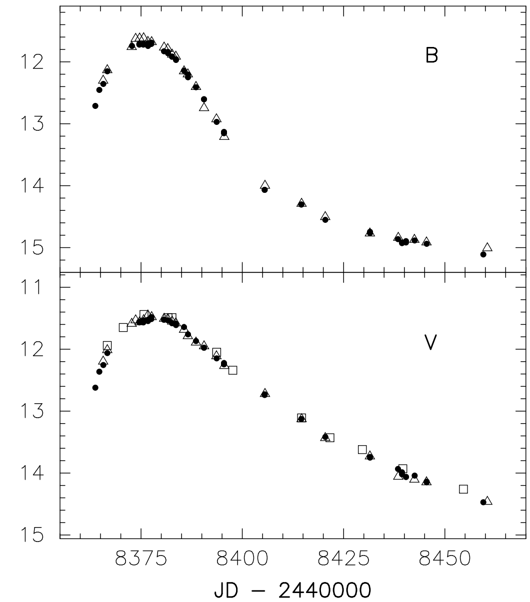

FIG. 6.—Comparison of our *B* and *V* light curves of SN 1991T (*circles*) with the preliminary photometric reductions of the CTIO data published by Phillips et al. (1992) (*triangles*). The *V* magnitudes from the Van Vleck Observatory study by Ford et al. (1993) are plotted as squares.

In Figure 9, we plot the late-time photometry of SN 1991T from this study and Schmidt et al. (1994) along with the predicted trend of the late-time evolution based on the $\gamma(B)$ and $\gamma(V)$ fits to our data. The fact that the light curve past day 400 levels off has been shown by Schmidt et al. (1994) to be due to a light echo with $(B, V) \sim (21.3, 21.4)$.

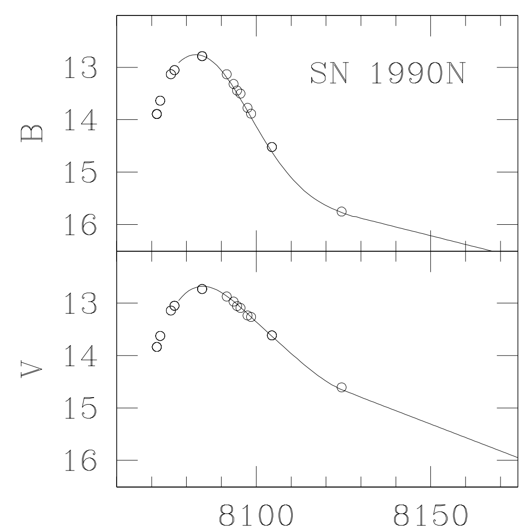

FIG. 7.—*BV* light curves of SN 1990N compared with the SN Ia template curves determined by Leibundgut (1988). The abscissa is plotted in units of days as JD − 2,440,000.

TABLE 8

PSKOVSKII AND PHILLIPS PARAMETERS

Object	$\Delta m_{15}(B)$ (mag)	$\beta(B)$ (mag [100 days]$^{-1}$)	Light Curve Range (days)	γ (mag [100 days]$^{-1}$)	Light Curve Range (days)
SN 1990N	1.03 ± 0.06	11.03 ± 0.13	11–22	1.380 ± 0.004	42–273
SN 1991T	0.95 ± 0.05	10.21 ± 0.09	10–20	1.381 ± 0.007	55–254
Leibundgut template......	1.10	11.29	...	1.676	...

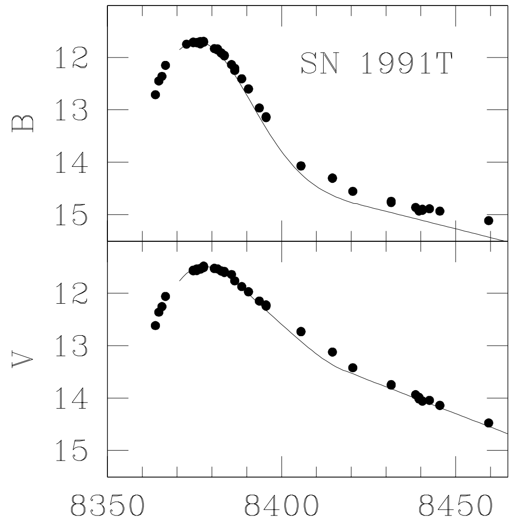

FIG. 8.—Same as Fig. 7, but for SN 1991T. The data appear to fall from maximum more slowly than the template curves.

Recall that in our work we subtracted a late-time image of the region taken around JD 2,449,380 around the supernova to remove the galactic contribution to the background under the PSF. By doing this, however, we also automatically correct for the echo contamination. This assumption is valid provided that the echo magnitude did not change during the period between the supernova observations and the late-time image and that the light curve of supernova did not level off for other reasons, such as the overproduction of ^{44}Ti or ^{22}Na. Under these assumptions, the photometry of SN 1991T in Table 6 and Figure 9 should be free of any echo contamination. Indeed, the small differences between our last points and those of Schmidt et al. at JD 2,448,750 shown in Figure 9 are consistent with the echo magnitude cited above.

3.2. *Color Curves*

The $B-V$, $B-R$, $B-I$, $V-R$, $V-I$, and $R-I$ color curves for SNe 1990N and 1991T through day 100 are shown in Figures 10 and 11, respectively. The temporal axis

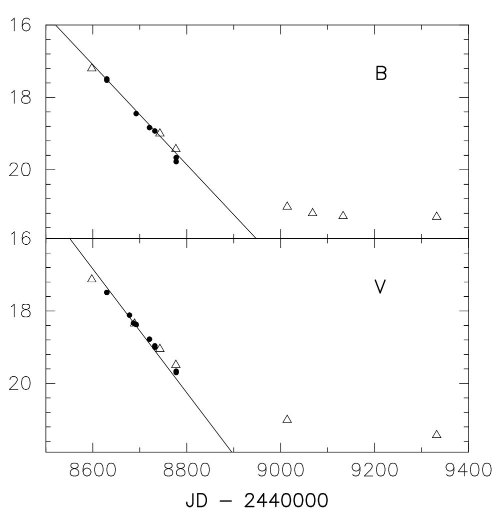

FIG. 9.—Late-time *BV* light curves for SN 1991T. Photometry from CTIO (*circles*) and from KPNO (*triangles*) are shown. An estimated decline rate for Type Ia supernovae based on the Pskovskii γ-parameter is also plotted.

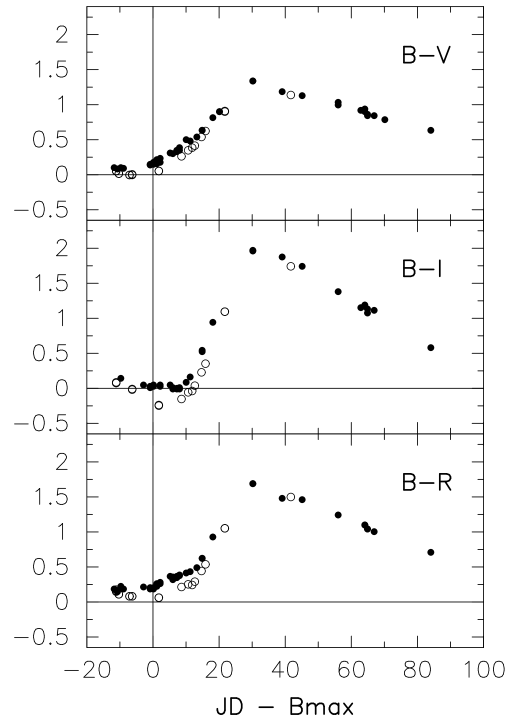

FIG. 10.—Observed $B-V$, $B-I$, and $B-R$ color evolution for SN 1990N (*open circles*) and SN 1991T (*filled circles*) as a function of time since B_{max}.

was shifted so that the B maximum corresponds to $t = 0$ for both supernovae. The redder color of SN 1991T with respect to SN 1990N is evident. The presence of redshifted Na absorption lines in the spectrum of SN 1991T and the location of the supernova in one of the arms of NGC 4527 suggest that this object was obscured by dust in its parent

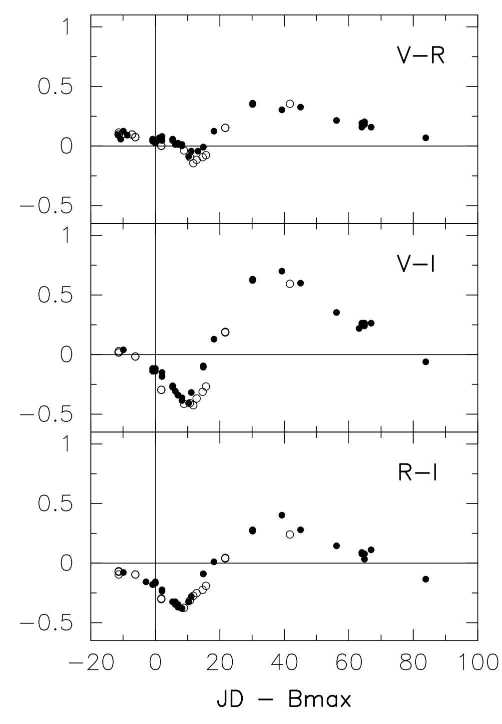

FIG. 11.—Observed $V-R$, $V-I$, and $R-I$ color evolution of SN 1990N (*open circles*) and SN 1991T (*filled circles*) as a function of time since B_{max}.

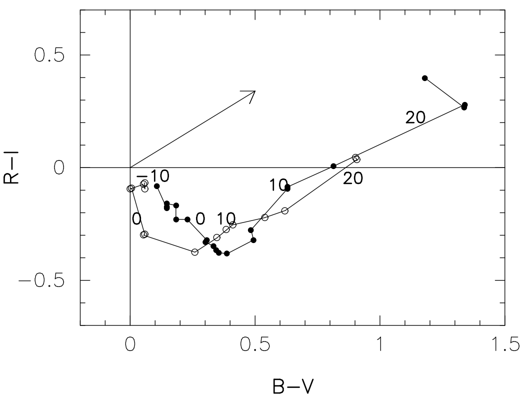

FIG. 12.—Observed $B-V$ vs. $R-I$ color-color curves for SN 1990N (*open circles*) and SN 1991T (*filled circles*). The numbers indicate the time elapsed in days since B maximum.

galaxy. Strong Ca and Na interstellar absorption lines at the radial velocity of NGC 4527 were observed by Wheeler & Smith (1991) and Meyer & Roth (1991). Ruiz-Lapuente et al. (1992) estimated an excess $E(B-V) \sim 0.3$, assuming a relationship between the equivalent width of the Na I D line and $E(B-V)$. On the other hand, Phillips et al. (1992) found an excess of 0.13 mag by assuming an intrinsic color $B-V$ of zero during maximum. The foreground $E(B-V)$ reddening is 0.00 ± 0.015 according to Burstein & Heiles (1994).

SN 1990N did not show absorption lines in a low-dispersion spectrum (Leibundgut et al. 1991), and its location in the outskirts of NGC 4639 suggests that this object is less reddened than SN 1991T. Saha et al. (1996) estimate the mean extinction of the Cepheids as $E(V-I) = 0.04 \pm 0.06$ based on the difference in distance moduli from Cepheid *VI* period-luminosity relations. The foreground $E(B-V)$ reddening is 0.012 ± 0.015 according to Burstein & Heiles (1994). It is unfortunate that no high-dispersion spectrum of this bright object was made. The $B-V$ color of 0.03 is consistent with an intrinsic color at maximum of approximately -0.1 to 0.1 mag for other Type Ia supernovae with low reddenings (Hamuy et al. 1991; Sandage & Tammann 1993; Hamuy et al. 1995) and suggests $E(B-V) \lesssim 0.15$. Lira (1996) has shown that the color evolution in *BV* from day 32 to 92 during the nebular phase is extremely uniform among Type Ia supernovae. In a future paper we will use this fact to calibrate the intrinsic colors of Type Ia supernovae at maximum, which, in turn, should allow more precise estimates to be made of the host galaxy reddening.

Differences in the color evolution of the two supernovae are better appreciated in the color-color plot shown in Figure 12. Time along the light curve is indicated by labeling the points at approximately -10, 0, 10, and 20 days from the maximum. The figure also shows the reddening vector for a Galactic extinction law (Savage & Mathis 1979). For $t > 10$ days, the curves are parallel to the reddening vector. However, the data from $t = -10$ to $t = 10$ show that the color curve of SN 1991T cannot be matched to that of SN 1990N by a simple dereddening vector.

4. CONCLUDING REMARKS

SNe 1990N and 1991T are important supernovae. They were close enough that distances to the host galaxies can (or will) be measured by direct techniques with *HST*. The light curves are especially well determined over the full evolution, and, in particular, the evolution before maximum is well covered. The light curves of these supernovae have become standard templates used in the study of more distant supernovae.

The photometric data presented in this paper show that SN 1990N was a typical Type Ia event, in that the light curves are well fitted by the template curve determined by Leibundgut (1988). It also falls in the middle of the range of Δm_{15} types defined by Phillips (1993). The spectral evolution of SN 1990N has also been classified as similar to other prototypical Type Ia supernovae, although the early observations caused it to be claimed as a peculiar object (Leibundgut et al. 1991).

The preliminary reductions of the SN 1990N data in Leibundgut et al. (1991) have been used by Sandage et al. (1996) to estimate a peak absolute magnitude for this supernova. The peak magnitudes cited by Sandage et al. of $(B, V) = (12.70, 12.61)$ are ~ 0.07 mag brighter than the more precise results given in Table 7. Such a small magnitude difference will have little effect on the measurement of the Hubble constant since $\delta H_0/H_0 \approx 0.46\delta m$. Hamuy et al. (1996b), Sandage et al. (1996), and Riess et al. (1996) have used the light curve of this supernova as one of the fundamental calibrators of the absolute magnitudes of Type Ia supernovae. These absolute magnitudes, coupled with the observed Hubble diagram from the Calán/Tololo survey (Hamuy et al. 1996b), have yielded $H_0 \sim 65$ km s^{-1} Mpc^{-1}.

Because of its peculiar nature, SN 1991T has been studied intensively. The peculiarities of this supernova include pre-maximum spectra dominated by iron-group features, a very small Δm_{15} value, and a visual luminosity larger than other typical Type Ia supernovae, although the derived absolute magnitudes depend strongly on the different extinction assumed for the supernova and the distance to the host galaxy, NGC 4527 (Filippenko et al. 1992; Ruiz-Lapuente et al. 1992; Phillips et al. 1992). The results of this paper confirm the slow evolutionary rate near maximum and also show that the color curve is significantly different from more normal Type Ia supernovae.

This is not to say that SN 1991T is unique, as new events of this "slow class" have been found, such as SNe 1991ag (Hamuy et al. 1995), 1992bc (Maza et al. 1994), 1995ac (Garnavich et al. 1996), and 1997br (Qiao et al. 1997b). The evidence suggests that the decline rate of these supernovae is just the slow end of the peak luminosity–decline rate relation for Type Ia supernovae and that this correlation could be also extended to a spectroscopic sequence (Nugent et al. 1995). Hamuy et al. (1996c) and Garnavich et al. (1996), however, have pointed out that the intrinsic luminosity, spectral features, and colors at maximum light are not a simple function of the light-curve shape (as measured by Δm_{15}) for this bright class of supernovae. For instance, among supernovae with similarly small values of Δm_{15}, SNe 1991T, 1995ac, and 1997br had very weak Si II λ6355 at maximum light (Filippenko & Leonard 1995; Qiao et al. 1997a) while 1992bc had the typical deep spectral features at maximum light common to most Type Ia events (Maza et al. 1994). Conversely, SN 1995bd had a spectrum similar to SN 1991T at maximum light, but its light curve was well fitted by the "faster" Leibundgut template (Garnavich et al. 1996). It is clearly important to obtain more examples of this class of bright Type Ia supernovae to sort out this issue.

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ERRATUM: "OPTICAL LIGHT CURVES OF THE TYPE Ia SUPERNOVAE SN 1990N AND SN 1991T" [ASTRON. J. 115, 234 (1998)]

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The following errors were brought to our attention by Brian Skiff of the Lowell Observatory.

In Table 3, two local standard stars were omitted, leading to confusion between the stars listed and those shown in Figure 1 of the paper. We provide a corrected version of the table below.

TABLE 3
PHOTOMETRIC SEQUENCE FOR SN 1990N

Star[a]	*n*	*m*	*V* (m.e.) (mag)	*B* − *V* (m.e.) (mag)	*V* − *R* (m.e.) (mag)	*R* − *I* (m.e.) (mag)	*U* − *B* (m.e.) (mag)
1	5	9	15.728 (005)	1.076 (009)	0.646 (006)	0.512 (011)	1.002 (026)
2	5	8	17.810 (003)	0.659 (007)	0.414 (004)	0.457 (009)	0.013 (012)
3	7	13	18.514 (004)	0.702 (005)	0.453 (005)	0.457 (006)	0.013 (021)
4	6	12	17.118 (004)	0.623 (006)	0.379 (005)	0.362 (006)	0.074 (009)
5	7	13	18.846 (005)	0.730 (007)	0.435 (006)	0.408 (009)	0.280 (033)
6	7	13	18.622 (005)	0.519 (008)	0.333 (006)	0.362 (009)	−0.086 (024)
7	6	12	17.707 (003)	0.735 (006)	0.414 (004)	0.402 (005)	0.068 (018)
8	3	6	17.626 (003)	1.468 (006)	0.940 (004)	0.933 (005)	1.256 (092)
9[b]	7	12	19.543 (005)	0.479 (010)	0.377 (006)	0.466 (010)	−0.129 (021)
10[b]	7	12	19.573 (010)	0.863 (026)	0.539 (013)	0.705 (014)	−0.269 (074)
11	5	9	16.580 (004)	0.615 (007)	0.385 (006)	0.351 (006)	0.040 (008)
12	7	13	19.140 (007)	1.484 (023)	1.104 (013)	1.509 (014)	0.601 (066)
13[b]	7	12	19.571 (011)	1.074 (033)	0.543 (012)	0.588 (013)	−0.340 (055)
14	3	7	20.104 (024)	1.089 (045)	0.566 (025)	0.592 (031)	−0.283 (085)
15	5	9	18.467 (010)	1.285 (021)	0.860 (011)	0.871 (006)	0.941 (062)
16	4	9	16.602 (005)	1.455 (007)	0.955 (009)	0.996 (009)	1.072 (031)
17[c]	3	6	13.392 (001)	0.607 (002)	0.356 (002)	0.341 (003)	0.031 (200)

[a] See Fig. 1.
[b] Object may be a galaxy.
[c] GSC 0881-0282.

The coordinates for SN 1990N and SN 1991T quoted in the paper are in error. The correct coordinates for equinox J2000.0 are as follows: SN 1990N, R.A. = $12^{h}42^{m}56\overset{s}{.}74$, decl. = $+13^{\circ}15'24\overset{''}{.}0$ (C. Pollas, IAU Circ. 5040 [1990]); SN 1991T, R.A. = $12^{h}34^{m}10\overset{s}{.}21$, decl. = $+02^{\circ}39'56\overset{''}{.}6$ (R. H. McNaught, IAU Circ. 5239 [1991]). An image of SN 1991T approximately 12 days before maximum can be seen on the second-generation Digitized Sky Survey.