A NEW FAINT TYPE Ia SUPERNOVA: SN 1997cn IN NGC 5490

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ABSTRACT

Observations of the recent supernova (SN) 1997cn in the elliptical galaxy NGC 5490 show that this object closely resembles, both photometrically and spectroscopically, the faint SN Ia SN 1991bg. The two objects have similar light curves, which do not show secondary maxima in the near-IR as normal type Ia supernova. The host galaxy, NGC 5490, lies in the Hubble flow. Adopting for SN 1997cn a reddening $(E(B-V)) = 0$, the absolute magnitude is faint: $M_V = -17.98$ using $H_0 = 65$ and $M_V = -17.40$ using $H_0 = 85$ km s$^{-1}$ Mpc$^{-1}$. The latter value is in close agreement with the absolute magnitude of SN 1991bg on the SBF/PNLF/TF distance scale. The photospheric spectra of the two SNe show the same peculiarities, the deep Ti II trough between 4000 and 4500 Å, the strong Ca II IR triplet, the narrow absorption at about 5700 Å, and the slow expansion velocity. Analogous to SN 1991bg, the observed spectrum of SN 1997cn has been successfully modeled by scaling down the W7 model by a factor of 2, assuming a rise time to $B$ maximum of 18 days, a photospheric velocity, and an effective temperature low compared to normal SNe Ia. The influence of the distance scale adopted on the input parameters of the best-fit model is also discussed.

These data demonstrate that peculiar SNe Ia like SN 1991bg are not once in a lifetime events and that deep SN searches can be contaminated by underluminous SNe Ia in a fairly large volume.

Key words: galaxies: evolution — stars: Population II — supernovae: general — supernovae: individual (SN 1997cn, SN 1991bg)

1. INTRODUCTION

Type Ia supernovae (SNe) have been used for decades as standard candles up to cosmological distances because of their high luminosity and apparent homogeneity. However, starting from the late 1980s, this latter property has been challenged (e.g., Branch 1987). In 1991 two objects were discovered, the faint SN 1991bg (Filippenko et al. 1992a; Leibundgut et al. 1993; Turatto et al. 1996) and the bright SN 1991T (Filippenko et al. 1992b; Ruiz-Lapuente et al. 1992; Phillips 1992), which unambiguously demonstrated that SNe Ia experience a wide range in luminosities, expansion velocities, and effective temperatures. More recently, accurate analyses of recent high-quality data (e.g., Phillips 1993; Riess et al. 1996) have shown that the diversity among SNe Ia is not limited to some peculiar cases, and that even “normal” SNe Ia cover a range of properties at either end of which reside the two extreme objects mentioned above.

The observations at both early and late epochs seem to require a range of one order of magnitude both in the mass of radioactive material and in the total mass of the exploding stars (Cappellaro et al. 1997). This is reflected in the kinetic energy of the ejecta (Mazzali et al. 1998). Hence the standard scenario for SNe Ia progenitors, that is, a white dwarf accreting mass up to the Chandrasekhar limit, has been challenged, and new progenitors are being investigated (e.g., Hoflich & Khokhlov 1996). In these models, variable amounts of heavy elements are produced and returned to the ISM via the explosion. Since SNe Ia may have a diversity of progenitors, the current models of galaxy chemical evolution should be revised. Obviously, the observed diversity has also major implications for the use of SNe Ia as distance indicators.

Although we are now aware of the diversity within SNe Ia, we do not know yet the distribution of SNe Ia with respect to these properties. Are extreme cases like SN 1991bg and SN 1991T just rare events, which do not affect the average properties of the overwhelming majority of “normal” SNe Ia? Are they distinct subtypes, or do they represent the extremes of a continuous distribution of properties? Are intrinsically faint events severely underestimated, to the extent that they may be so frequent as to constitute the majority of SNe Ia?

So far only four intrinsically dim SNe Ia have been discovered: the prototype SN 1991bg, SN 1986G (Phillips et al. 1987; Cristiani et al. 1992), SN 1992K (Hamuy et al. 1994), and SN 1991F (Gomez & Lopez 1995). However, the last three did not share the same extreme properties as SN 1991bg (cf. Turatto et al. 1996 and references therein).

In this paper, we present the observations of a new candidate member (Turatto et al. 1997) of the class of faint SNe Ia and discuss its properties. SN 1997cn was discovered on May 14.6 UT (Li et al. 1997) 6.7 east and 11.7 south of the nucleus of the relatively distant elliptical galaxy NGC 5490 ($V_{3K} = 5246$ km s$^{-1}$; RC3).

2. OBSERVATIONS

The data presented in this paper were collected at ESO, La Silla, with different telescopes (cf. Tables 1 and 3 below) starting soon after discovery and until the object became too faint for our instrumentation.

The SN photometry is given in Table 1. The photometry was obtained with respect to a local sequence (Fig. 1) calibrated with respect to the photometric sequence around
TABLE 1

UBV(RI)_c PHOTOMETRY OF SN 1997cn AT LA SILLA

| Date       | JD (2,450,000+) | U     | B     | V     | R_C  | I_C  | Telescope* |
|------------|-----------------|-------|-------|-------|------|------|------------|
| 1997 May 23 | 592.06          | 18.17 (0.10) | 17.46 (0.05) | 16.62 (0.05) | 16.39 (0.05) | 16.40 (0.05) | 1 |
| 1997 May 27 | 595.96          | 19.10 (0.10) | 18.24 (0.05) | 17.10 (0.05) | 16.73 (0.05) | 16.52 (0.05) | 1 |
| 1997 May 27 | 596.00          | ...     | 18.29 (0.05) | ...     | ...     | ...     | 1 |
| 1997 May 30 | 598.89          | 19.17 (0.10) | 18.70 (0.05) | 17.40 (0.05) | 16.91 (0.05) | 16.72 (0.05) | 1 |
| 1997 May 31 | 599.95          | 19.33 (0.10) | 18.82 (0.05) | 17.50 (0.05) | 17.00 (0.05) | 16.63 (0.05) | 1 |
| 1997 Jun 1  | 600.95          | ...     | ...     | 17.51 (0.05) | 17.09 (0.05) | 16.68 (0.05) | 1 |
| 1997 Jun 2  | 601.97          | 19.51 (0.20) | 18.86 (0.10) | 17.59 (0.10) | 17.10 (0.05) | 16.76 (0.05) | 1 |
| 1997 Jun 2  | 602.00          | ...     | ...     | 17.70 (0.10) | 17.16 (0.05) | ...     | 1 |
| 1997 Jun 3  | 602.90          | ...     | 18.93 (0.10) | ...     | ...     | ...     | 1 |
| 1997 Jun 7  | 606.90          | 19.70 (0.15) | 19.32 (0.10) | ...     | 17.57 (0.05) | 17.28 (0.05) | 1 |
| 1997 Jun 7  | 607.00          | 19.62 (0.15) | 19.30 (0.10) | 18.10 (0.10) | 17.63 (0.05) | 17.23 (0.05) | 1 |
| 1997 Jun 15 | 614.66          | ...     | 19.88 (0.10) | 18.55 (0.10) | 18.16 (0.05) | 17.84 (0.10) | 3 |
| 1997 Jun 15 | 614.90          | 19.99 (0.20) | 19.63 (0.15) | 18.70 (0.15) | 18.21 (0.10) | ...     | 1 |
| 1997 Jun 16 | 615.95          | ...     | 19.72 (0.10) | 18.58 (0.10) | 18.17 (0.10) | 17.84 (0.10) | 1 |
| 1997 Jun 17 | 616.90          | ...     | ...     | ...     | 17.81 (0.10) | ...     | 1 |
| 1997 Aug 4  | 664.50          | ...     | ...     | 20.22 (0.20) | ...     | ...     | 2 |
| 1997 Aug 9  | 669.45          | ...     | ...     | 20.57 (0.20) | ...     | ...     | 3 |
| 1998 Feb 3  | 847.0           | ...     | ≥ 23.0 | ...     | ...     | ...     | 4 |

* (1) CCD camera at the Dutch 0.9 m telescope; (2) ESO Faint Object Spectrograph and Camera (EFSOSC2) at the ESO/MPI 2.2 m telescope; (3) DFOSC at the Danish 1.5 m telescope; (4) EFOSC2 at the ESO 3.6 m telescope.

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**Fig. 1.** — $V$-band image taken with the Dutch 0.9 m telescope on 1997 May 1. The stars of the local sequence used for calibrating the SN photometry (cf. Table 2) are identified.
Nova Sakurai (Duerbeck et al. 1997), which was observed on three photometric nights together with the SN field. Table 2 gives the magnitudes obtained for the SN local sequence and the internal errors for stars measured in different nights. In order to subtract the galaxy contribution, the PSF-fitting procedures implemented in the ROMAFOT package were used. The uncertainty in the SN photometry varied with time because of the decreasing contrast of the SN against the galaxy background. Estimates of the errors, ranging from 0.05 mag at early epochs to 0.2 mag in the later $V$ observations, are reported in parentheses.

The spectra (Table 3) were calibrated using a standard technique, including flat-fielding, optimal extraction, and wavelength and flux calibration with respect to spectrophotometric standard stars observed on the same nights.

In Figure 2 we show the light curves of SN 1997cn in $UBVRI$. Clearly, the monitoring started when the SN had just passed maximum light. However, the templates plotted in Figure 2 show that the light curve of SN 1997cn resembles closely in shape that of SN 1991bg. Thus we can confidently estimate the epochs and the magnitudes of the maxima in the various bands (cf. Table 4). The discovery magnitude ("mag about 15.8 on an unfiltered CCD frame"; Li et al. 1997) is somewhat inconsistent with the rest of the light curve, but we choose to ignore it because it is not in a defined photometric band. At the epoch of the last observation the SN was not detected. Unfortunately, the photometric detection limit is not deep enough to establish the late decline rate.

As with SN 1991bg, SN 1997cn faded monotonically in $R$ and $I$, showing no sign of the secondary maxima characteristic of the light curves of "normal" SNe Ia in the near IR. A comparison with SN 1994D (Patat et al. 1996) in Figure 3 illustrates this difference. Also, the $B-V$ color curve of SN 1997cn is different from that of "normal" SNe Ia and similar to, although slightly bluer than that of SN 1991bg (cf. Fig. 3).

### 3. DATA ANALYSIS AND MODELING

Phillips (1993) showed that the rate of decline of the light...
curve after maximum light correlates with the absolute magnitude at maximum. This was confirmed by Hamuy et al. (1996) for a larger sample of SNe. Riess et al. (1996) extended the treatment to show that the whole shape of the light curve depends on the absolute magnitude at maximum. Since the light curve of SN 1997cn is very similar to that of SN 1991bg, we can use the above-mentioned correlations to predict that the absolute magnitude of SN 1997cn is faint.

To quantify this indication we can use both the relation between the peak luminosity and $\Delta m_{15}$ (Phillips 1993; Hamuy et al. 1996) and the multicolor light-curve shape (MLCS) technique (Riess et al. 1996). The MLCS method is based on the comparison between the $BVRI$ light curves of a SN and those of well observed objects defining a training set. Applying this method to SN 1997cn we obtain a value of the "luminosity correction" $\Delta = 1.50 \pm 0.05$. This should be compared with values $\Delta = 1.44$ for SN 1991bg and $\Delta = 1.25$ for SN 1992K (Riess et al. 1996). Taken at face value, the MLCS method indicates a “negative” reddening $E(B-V) = -0.10$. This simply tells us that SN 1997cn was bluer than SN 1991bg, the object used to define the behavior of faint SNe Ia (Riess et al. 1996). In that work it was assumed that $E(B-V) = 0$ for SN 1991bg, while some small reddening was probably present [$E(B-V) = 0.05$; Turatto et al. 1996]. Considering that the parent galaxy is elliptical, that Galactic extinction is $A_B = 0.0$ (Burstein & Heiles 1984), and the MLCS indication, we conclude that SN 1997cn did not suffer from any reddening along the line of sight.

To estimate the distance modulus of NGC 5490 we must rely on the recession velocity and adopt a value for the Hubble constant. A value of $H_0 = 85$ km s$^{-1}$ Mpc$^{-1}$ gives $m - M = 33.95$, whereas $H_0 = 65$ implies $m - M = 34.53$. Based on the observed magnitude at maximum, we obtain $M_V = -17.40$ ($H_0 = 85$) or $M_V = -17.98$ ($H_0 = 65$). As we will discuss below, the different luminosity calibrations correspond to different solutions for the spectrum synthesis model.

Regardless of the adopted distance scale the SN was quite faint. Indeed the fainter value is in close agreement with the absolute magnitude of SN 1991bg, $M_V = -17.28$ (Turatto et al. 1996). The magnitude of SN 1991bg, which was derived using the SBF/PNLF/TF distance scale (e.g., Vaughan et al. 1995), is consistent with $H_0 = 85$.

The rate of decline in the first 15 days after maximum is $\Delta m_{15}(B) = 1.86$. This value is very close to that of SN 1991bg [$\Delta m_{15}(B) = 1.95$, Turatto et al. 1996], suggesting that the two SNe reached about the same luminosity at maximum. One can note that SN 1991bg and SN 1997cn deviate from the linear relation between $\Delta m_{15}$ and absolute magnitude as defined from "average" SNe Ia (Hamuy et al. 1996). The other faint SN Ia, SN 1992K, seems to conform to this relation, but since the first observations of SN 1992K were obtained only 10 days after maximum the value of $\Delta m_{15}$ is quite uncertain.

The spectral evolution of SN 1997cn is outlined in Figure 4, where we have compared the spectra of SN 1997cn and SN 1991bg at two different epochs. The maximum light spectrum of SN 1997cn, which was used for the early SN classification (Turatto et al. 1997), is different from those of normal SNe Ia and resembles closely that of SN 1991bg. In particular, this is true in the region between 4200 and 4500 Å, where both SNe show a broad absorption due to Ti II (Filippenko et al. 1992a; Mazzali et al. 1997). Also, the profile of the Si II 6355 Å line is the same, indicating a very slow expansion velocity of the ejecta. The only notable difference is in the intensity of the emission at 4600 Å, which is stronger in SN 1997cn than in SN 1991bg.

For the maximum epoch we have computed the line ratio $R$(Si II) (Nugent et al. 1995), which defines a spectroscopic

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### Table 4

**Main Data of SN 1997cn**

| Parameter                      | U    | B    | V    | R    | I    |
|-------------------------------|------|------|------|------|------|
| Epoch of maximum (JD + 2450000) | 588 ± 2 | 588 ± 1 | 589 ± 1 | 589 ± 1 | 589 ± 1 |
| Magnitude (maximum)           | 18.2 ± 0.2 | 17.2 ± 0.1 | 16.55 ± 0.1 | 16.3 ± 0.1 | 16.35 ± 0.1 |
| $\Delta m_{15}$               | 1.47 | 1.86 | 1.18 | 0.97 | 0.60 |
| Luminosity correction $\Delta$ | -15.75 | -16.75 | -17.40 | -17.65 | -17.60 |

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* $H_0 = 85; E(B-V) = 0.0$. 

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**Figure 3** — Comparison of the absolute $V$ and $I$ light curves and $B - V$ color curves of SN 1997cn (filled symbols) with those of SN 1991bg (circles), SN 1992K (triangles), and SN 1994D (pentagons). The similarity with SN 1991bg both as to luminosity and light-curve shape is evident. Note the absence of the secondary maximum in the $I$ band and the early turnover of the $B - V$ color curve. The distance moduli adopted are in the SBF/PNLF/TF distance scale compatible with $H_0 = 85$ km s$^{-1}$ Mpc$^{-1}$ [$\mu(97\text{cn}) = 33.95$, $\mu(91\text{bg}) = 31.09$, $\mu(92 \text{K}) = 32.96$ and $\mu(94\text{D}) = 30.68$]. The reddening are $E(B-V)(97\text{cn}) = 0.00$, $E(B-V)(91\text{bg}) = 0.05$, $E(B-V)(92 \text{K}) = 0.12$, and $E(B-V)(94\text{D}) = 0.06$ are accounted for.
sequence for SNe Ia with values ranging from $R = 0.14$ for SN 1991T to $R = 0.62$ for SN 1991bg. For SN 1997cn we measured $R(\text{Si} \, 
\text{II}) = 0.63$, which is very similar to the value for SN 1991bg, as expected. The value of $R(\text{Ca} \, 
\text{II})$ is rather uncertain for SN 1997cn because of the poor signal-to-noise ratio of our spectrum at this wavelength.

The second comparison is between SN 1997cn and SN 1991bg using spectra taken about one month after maximum. The spectra are again very similar, with the same line intensity ratios and widths. The difference in the intensity of the continuum below 5000 Å is probably due to a poor galaxy background subtraction in the noisy spectrum of SN 1997cn. The Ca II IR triplet is very strong in both objects compared with other SNe Ia (cf. Fig. 8 of Turatto et al. 1996). The very narrow absorption at about 5700 Å, which was one of the most mysterious features of SN 1991bg (Turatto et al. 1996), is visible in SN 1997cn as well.

We also obtained a spectrum of SN 1997cn 2.5 months after discovery. Although the spectrum is very noisy, it does resemble the spectrum of SN 1991bg at 79 days after maximum. In particular, the $\text{[Ca} \, 
\text{II}] \lambda \lambda 7291, 7324$ emission is very strong. This line is also the dominant feature in the nebular spectra of SN 1991bg.

We have modeled the maximum light spectrum of SN 1997cn using the new version of the Monte Carlo spectrum synthesis code by Mazzali & Lucy (1998), which includes photon branching. Since SN 1997cn and SN 1991bg are so similar, we fitted SN 1997cn using parameters similar to those used to fit the maximum light spectrum of SN 1991bg (Mazzali et al. 1997). Those results are summarized here. The best fit for SN 1991bg was obtained using $\mu = 31.13$ for NGC 4374, which corresponds to a short distance scale. We used $E(B-V) = 0.05$ for the reddening and obtained a best fit by assuming that the exploding mass was only $0.7 M_\odot$, derived by scaling the W7 density structure (Nomoto 1984) down by a factor of 2. Maximum light was assumed to occur 18 days after the explosion. The best-fitting model had luminosity log $(L/L_\odot) = 42.33$ ergs s$^{-1}$ and photospheric velocity $v_{p} = 6750$ km s$^{-1}$, so that the effective temperature was $T_{\text{ph}} = 7050$ K. The abundances were ad hoc; that is, compared with W7, O was increased, the Fe-group elements decreased, and, among the intermediate-mass elements, Si was decreased and S increased, indicating that burning had been much less effective in SN 1991bg than in normal SNe Ia. The resulting synthetic spectrum had absolute magnitudes $V = -17.3$ and $B = -16.7$. The new model, which includes photon cascades, can explain the reemission feature at 4500 Å, which was not reproduced with the previous pure scattering model.

The near-maximum-light spectrum of SN 1997cn was obtained on 1997 May 22, that is, three days after $B$ maximum. We therefore used $t = 21$ days, consistent with a rise time to $B$ maximum of 18 days as for SN 1991bg. Since the spectra of SN 1997cn and SN 1991bg are so similar, we assumed that the temperature was the same in both, even though the epoch is slightly different. We used the same luminosity as in the maximum light SN 1991bg model [$\log (L/L_\odot) = 42.33$ ergs s$^{-1}$], an assumption that is justified by the rather flat shape of the light curve of SN 1991bg around maximum (Turatto et al. 1996). We then rescaled the photospheric velocity to a value that would yield the same $T_{\text{ph}}$ at the new epoch, that is, $v_{\text{ph}} = 6000$ km s$^{-1}$. Both the photospheric velocity and the effective temperature are low with respect to the values for a normal SN Ia. We refer the reader to the paper discussing modeling of SN 1991bg (Mazzali et al. 1997) for a more detailed discussion of the effects of these quantities on the synthetic spectra. We used a distance $\mu = 33.95$, and reddening $E(B-V) = 0.0$. The synthetic spectrum thus computed reproduces well both the spectrum of SN 1997cn at $t = 21$ days and that of SN 1991bg at $t = 18$ days (Fig. 5).

Although a more detailed description of the new Monte Carlo code will be presented elsewhere, we note that with this new version the amount of Ti II needed to model the spectrum of SN 1991bg increases from $7 \times 10^{-5}$ (Mazzali et al. 1997) to 0.005 $M_\odot$, probably because of the new atomic data. A small difference between the two observed spectra (SN 1997cn and SN 1991bg) is the depth and the shape of the Ti II trough between 4000 and 4500 Å, so that a mass of Ti of 0.002 $M_\odot$ above the photosphere gives the best fit to the spectrum of SN 1997cn.

In the model, increasing only the luminosity results in a higher photospheric temperature. However, for even a small increase of the temperature, the shape of the spectrum changes and the fit becomes unacceptable. Clearly, a good fit can only be obtained with a very specific $T_{\text{ph}}$. In order to conserve that temperature, the photospheric radius must be increased along with the luminosity. If we adopt a distance $\mu = 34.53$, the luminosity increases by 0.58 mag to $\log (L/L_\odot) = 42.56$, and the velocity must increase from 6000 to 7750 km s$^{-1}$. Since the mass above the photosphere is smaller for a model with higher $v_{\text{ph}}$ and a constant exploding mass of 0.7 $M_\odot$ (0.38 $M_\odot$ vs. 0.48 $M_\odot$ for the lower $v_{\text{ph}}$ model), the synthetic lines are too shallow. This can be circumvented by adopting a higher exploding mass. A model with the larger distance, the same input parameters just listed and a mass of 1.4 $M_\odot$ gives a fit of the same quality as the short distance, low velocity, small mass model. The difference in the photospheric velocity is in fact too small to be noticeable.

Current problems with the sub–Chandrasekhar explosion scenario (in particular the predicted but not observed presence of an outer Ni shell in current He-detonation models) may be used as an argument in favor of the long distance scale. However, if we adopt the long distance scale for SN 1997cn and of course also for SN 1991bg, the same argument should then be applied to normal SNe Ia. This

![Fig. 4.—Comparison of the spectra of SN 1997cn and SN 1991bg in proximity of maximum and one month later.](image-url)
Fig. 5.—Maximum light spectrum compared with the model spectrum obtained for a W7 density structure scaled to a total mass of 0.7 $M_\odot$, log $L = 42.33$, photospheric velocity $v_{ph} = 6000$ km s$^{-1}$, rise time to $B$ maximum is $t = 21$ days. No reddening has been adopted. Main line identifications are marked.

may lead to masses significantly in excess of the Chandrasekhar limit, and so we would only be shifting the problem from faint to average SN Ia models.

To be fair we can say that, because of the uncertainties in the progenitor scenarios, spectral synthesis modeling of the photospheric epoch alone are not sufficient to constrain the value of the Hubble constant, as already stressed for SN 1991bg. Greater insight can be obtained using late-time spectra as well, as was done for SN 1991bg. Unfortunately, SN 1997cn was too faint to be observable at such late epochs, but we expect that it would have had narrow lines, as did SN 1991bg.

We have also modeled the light curve of SN 1997cn using the simple Monte Carlo code described in Cappellaro et al. (1997). We have compared the synthetic bolometric light curve with the observed $V$ curve, assuming that the bolometric correction is small. The mass of Ni was assumed to be centrally concentrated. We find that for the short distance a Ni mass of $\sim 0.1 M_\odot$ is required to reproduce the maximum magnitude. The exact value of the ejecta mass depends on the kinetic energy (KE), which depends on the production of Ni but also on that of Si. Values of $M_{ej}$ between 0.4 and $0.7 M_\odot$ yield acceptable fits to the light curve depending on whether the KE per unit mass is rescaled according to the $M_{Ni}/M_{ej}$ ratio or not. In this latter case we assume that burning to Si provides the additional KE to make up for the small production of Ni.

In Figure 6 we show the fit to the observations of different models. In particular it appears that a good fit can be obtained for a model with $M_{ej} = 0.4 M_\odot$ and KE rescaled according to the $M_{Ni}/M_{ej}$ ratio. The assumption of no positron deposition leads to a better fit at late phases, as was the case for SN 1991bg. For the large distance a similarly good fit can be obtained for $M_{Ni} = 0.2 M_\odot$ and $M_{ej} = 0.55 - 1 M_\odot$. Thus the fast decline supports the sub–Chandrasekhar-mass option at both distances.

In conclusion, good fits to the spectra and the light curve can be obtained for both the short and the long distance scales. However, while in the case of short distances the ejecta masses indicated by the light curve and the spectra

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**Fig. 6.—** Comparison of the $V$ light curve of SN1997cn (triangles) with models. The dotted lines are the models obtained with 0.1 $M_\odot$ of Ni and 0.40 $M_\odot$ of ejecta transformed to apparent magnitudes with $\mu = 33.95$ ($H_0 = 85$). The short-dashed lines are models with 0.2 $M_\odot$ of Ni and 0.55 $M_\odot$ transformed to apparent magnitudes with $\mu = 34.53$ ($H_0 = 65$). Models with two different positron opacity $\tau_e$ are shown. It has been assumed that the bolometric correction is negligible and that $E(B-V) = 0.00$. 

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agree rather well ($\sim 0.7 M_\odot$), this is not the case for the long
distance, where the best-fit “spectroscopic mass” ($\sim 1.4$
$M_\odot$) is larger than the “photometric mass” ($\sim 1.0 M_\odot$).

4. CONCLUSION

We have presented a set of observations of the recent SN 1997cn that demonstrate that it is a faint SN Ia nearly
identical to SN 1991bg. In particular, we measured similar
values for the light-curve parameters $\Delta m_{15}$ and the lumi-
nosity correction $\Delta$, which are known to correlate with the
luminosity. The two SNe are also similar in that their light
curves lack the secondary maxima at red wavelengths
typical of normal SNe Ia, and they have similar color
curves. The two objects share also the same spectral appear-
ance, the rapid evolution, and the low temperature and
photospheric velocities.

The best-fit model depends on the luminosity cali-
ibrations: if we adopt a short distance scale we can fit the
spectrum adopting a W7 density profile scaled to a total
mass of the exploding star of $\sim 0.7 M_\odot$, as we did for SN
1991bg. The mass of radioactive material synthesized
during the explosion, which is the main parameter charac-
terizing SNe Ia (Cappellaro et al. 1997), was $0.05$–$0.15 M_\odot$
for SN 1991bg (Mazzali et al. 1997). If, on the other hand,
we adopt a long distance scale, a good fit can be obtained
with an unscaled W7 model. Even in this case, though, the
Ni mass would be only $\sim 0.2 M_\odot$, which is small for a
normal Chandrasekhar mass SN Ia.

In a recent paper (Mazzali et al. 1998) we have shown
that the luminosity decline rate after maximum light, $\Delta m_{15}$,
is correlated with the expansion velocity of the Fe core
measured from the width of the nebular lines. Since $\Delta m_{15}$ is
correlated with the absolute magnitude at maximum, which
in turn is directly related to the $^{56}$Ni mass, this finding
suggests that the amount of radioactive material synthe-
sized is directly correlated with the kinetic energy of the
ejecta. At low expansion velocities this relation is based on
the observations of only SN 1991bg. Unfortunately our
attempt to recover SN 1997cn in the nebular stage was
unsuccessful, and we could only place an upper limit, which
is, however, consistent with a behavior similar to that of SN
1991bg.

A common concern is that faint SNe Ia could be fairly
frequent and therefore severely underestimated in current
searches. A recurrent argument is that indeed faint SNe are
only found in nearby galaxies. We note, however, that
modern CCD searches are more effective in discovering
faint, red objects like SN 1991bg and SN 1997cn than tradition-
ally searches that use blue-sensitive photographic plates.
The discovery of SN 1997cn in a relatively distant galaxy
confirms that such searches are indeed able to discover faint
SNe Ia in a fairly large volume. Thus, the question of the
intrinsic frequency of faint SNe Ia will hopefully be settled
within the next few years.

It is also worth mentioning that the parent galaxy of SN
1997cn is elliptical. In recent years evidence has been accu-
mulating that SNe Ia in elliptical galaxies are on the
average fainter that those in spiral galaxies. SN 1997cn is
obviously consistent in this respect. Again, the statistics still
need to be improved, but the idea that the progenitors of
SNe Ia in elliptical and spiral galaxies may originate in
different populations merits further investigation.

We are pleased to thank the Leiden Observatory and Mr.
Brogt, who kindly allowed the observations of SN 1997cn
at the Dutch telescope also during the Dutch reserved time.

REFERENCES

Branch, D. 1987, ApJ, 316, L81
Burbstein, D., & Heiles, C. 1984, ApJS, 54, 33
Cappellaro, E., Mazzali, P. A., Benetti, S., Danziger, I. J., Turatto, M.,
Della Valle, M., & Patat, F. 1997, A&A, 328, 203
Cristiani, S., et al. 1992, A&A, 259, 63
Duerbeck, H., Benetti, S., Gautschy, A., van Genderen, A. M., Kemper, C.,
Liller, W., & Thomas, T. 1997, AJ, 114, 1657
Filippenko, A. V., et al. 1992a, AJ, 104, 1543
1992b, ApJ, 384, L15
Gomez, G., & Lopez, R. 1995, AJ, 109, 737
Hamuy, M., et al. 1994, AJ, 108, 2226
Hamuy, M., Phillips, M. M., Schommer, R. A., Suntzeff, N. B., & Maza, J.
1996, AJ, 112, 2391
Howarth, P., & Khokhlov, A. M. 1996, ApJ, 457, 500
Leibundgut, B., et al. 1993, AJ, 105, 301
Li, W., Qiu, Y., Qiao, Q., Zhang, Y., Zhou, W., & Hu, J. 1997, IAU Circ.
6661
Mazzali, P. A., Cappellaro, E., Danziger, I. J., Turatto, M., & Benetti, S.
1998, ApJ, 499, L49
Mazzali, P. A., Chugai, N., Turatto, M., Lucy, L., Danziger, I. J., Cappel-
laro, E., Della Valle, M., & Benetti, S. 1997, MNRAS, 284, 151
Mazzali, P. A., & Lucy, L. 1998, MNRAS, 295, 428
Nomoto, K. 1984, ApJ, 277, 791
Nugent, P., Phillips, M., Baron, E., Branch, D., & Hauschildt, P. 1995, ApJ,
455, L147
Patat, F., Benetti, S., Cappellaro, E., Danziger, I. J., Della Valle, M.,
Mazzali, P. A., & Turatto, M. 1996, MNRAS, 278, 111
Phillips, M. M. 1993, ApJ, 413, L105
Phillips, M. M., et al. 1987, PASP, 99, 592
Phillips, M. M., Wells, L. A., Suntzeff, N. B., Hamuy, M., Leibundgut, B.,
Kirshner, R. P., & Foltz, C. B. 1992, AJ, 103, 1632
Riess, A. G., Press, W. H., & Kirshner, R. P. 1996, ApJ, 473, 88
Ruiz-Lapuente, P., Cappellaro, E., Turatto, M., Gouiffes, C., Danziger, I. J.,
Della Valle, M., & Lucy, L. B. 1992, ApJ, 387, L33
Turatto, M., Benetti, S., Pereira, C., & Da Silva, L. 1997, IAU Circ. 6667
Vaughan, T. E., Branch, D., Miller, L., & Perlmutter, S. 1995, ApJ, 439, 558