ABSTRACT. Blue Supernovae of Type Ia (SNe Ia) have become the most important objects in cosmology being of exceptionally uniform luminosity. Used as relative distance indicators they map deviations from pure Hubble flow and determine the cosmological constant $\Lambda$. Once their absolute magnitude is determined they provide the best estimate of the large-scale value of the Hubble constant $H_0$. An HST project is reviewed where Cepheid distances are used for the luminosity calibration of SNe Ia. The mean luminosity of 8 SNe Ia is $M_B(\text{max}) = -19.47 \pm 0.07$, $M_V(\text{max}) = -19.48 \pm 0.07$, corresponding – after small corrections for second parameters – to $H_0(\text{cosmic}) = 59 \pm 5$.

1. Introduction

As the number of SNe Ia increased and their data improved it became increasingly clear that they are nearly perfect standard candles, i.e. that their luminosity scatter at any given epoch (e.g. at maximum) is $< 0.2$ mag (Kowal 1968; Sandage & Tammann 1982, 1993; Tammann 1979, 1982; Cadonau, Sandage, & Tammann 1985; Branch & Tammann 1992; Tammann & Sandage 1995; Hamuy et al. 1995, 1996a), if one excludes the few red SNe Ia, which are underluminous because of absorption and/or intrinsic peculiarities, and restricts oneself to blue, spectroscopically uniform (“Branch-normal”; Branch, Fisher, & Nugent 1993) SNe Ia with $(B_{\text{max}} - V_{\text{max}}) \leq 0.2$. The scatter becomes even smaller when small differences in decline rate and color are allowed for (Parodi et al. 1999, and sources therein). This gives SNe Ia a unique role in cosmology. Their apparent magnitudes can be used to map deviations from pure Hubble flow and hence to trace large-scale inhomogeneities (Tammann 1998a, 1999; Zehavi et al. 1998), as well as to determine the value of the cosmological constant $\Lambda$ (Perlmutter et al. 1999; Schmidt et al. 1998); in the latter case one depends, of course, on the absence of secular luminosity evolution effects (cf. Kobayashi et al. 1998).

In addition, if it is possible to calibrate the luminosity of SNe Ia in absolute terms, one can derive unparalleled distances to better than 10% to all galaxies which have produced well observed SNe Ia and determine the Hubble constant $H_0$ out to velocity distances of 30,000 km s$^{-1}$. This distance range is ideally suited because one is bound to find here the truly cosmic value of $H_0$, unperturbed by peculiar velocities, and yet the K-correction is still small and space curvature effects negligible.
For the luminosity calibration of SNe Ia a small HST team has been formed comprising A. Sandage, A. Saha, L. Labhardt, F. D. Macchetto, N. Panagia, & G. A. Tammann. They have observed so far the Cepheids in six galaxies having produced seven SNe Ia with good or even excellent light curve coverage. The resulting Cepheid distances yield the absolute magnitudes $M_B$ and $M_V$ of the SNe Ia at maximum light. Their results shall be reported in the following. The reader is also referred to other reviews on the subject (Saha 1998, 1999; Macchetto & Panagia 1999).

The reliability of Cepheids is briefly discussed in Sec. 2. The results concerning SNe Ia are compiled in Sec. 3. A discussion of second-parameter effects is found in Sec. 4. The conclusions are in Sec. 5.

2. Cepheids as Distance Indicators

Cepheids are presently, through their period-luminosity (PL) relation, the most reliable and least controversial distance indicators. The slope and the zeropoint of the PL relation is taken from the very well-observed Cepheids in the Large Magellanic Cloud (LMC), whose distance modulus is adopted to be $(m - M) = 18.50$ (Madore & Freedman 1991).

An old PL relation calibrated by Galactic Cepheids in open cluster, and now vindicated by Hipparcos data (Sandage & Tammann 1998), gave $(m - M)_{LMC} = 18.59$ (Sandage & Tammann 1968, 1971). Hipparcos data combined with more modern Cepheid data give an even somewhat higher modulus (Feast & Catchpole 1997). Reviews of Cepheid distances (Federspiel, Tammann, & Sandage 1998; Gratton 1998) cluster around $18.56 \pm 0.05$, a value in perfect agreement with the purely geometrical distance determination of SN 1987A ($18.58 \pm 0.05$; Gilmozzi & Panagia 1999). In his excellent review Gratton (1998) concludes from the rich literature on RR Lyr stars that $(m - M)_{LMC} = 18.54 \pm 0.12$. He also discusses five distance determination methods which give lower moduli by 0.1 – 0.2 mag, but they are still at a more experimental stage. There is therefore emerging evidence that the adopted LMC modulus of 18.50 is too small by $\sim 0.06$ mag and that the SNe Ia luminosities derived in the next paragraph should be increased by this amount.

There has been much debate about the possibility that the PL relation of Cepheids depends on metallicity. The question is here of more principal than practical importance because the mean metallicity of the seven spiral galaxies and one Am galaxy considered below hardly differs by much from the Galactic metallicity. Direct observational evidence for a (very) weak metallicity dependence comes from the fact that the metal-rich Galactic Cepheids give perfectly reasonable distances for the moderately metal-poor LMC Cepheids and the really metal-poor SMC Cepheids and, still more importantly, that their relative distances are wavelength-independent (Di Benedetto 1997; cf. Tammann 1997). Much progress has been made on the theoretical front. Saio & Gautschy (1998) and Baraffe et al. (1998) have evolved Cepheids through the different crossings of the instability strip and have investigated the pulsational behavior at any point. The resulting (highly metal-insensitive) PL relations in bolometric light have been transformed into PL relations at different wavelengths by means of detailed atmospheric models; the conclusion is that any metallicity dependence of the PL relations is negligible (Sandage, Bell, & Tripicco 1998; Alibert et al. 1999; cf. however Bono, Marconi, & Stellingwerf...
While remaining uncertainties of the PL relation and the zeropoint seem to have only minor practical consequences, the application to HST observations is by no means simple. The photometric zeropoint, the linearity over the field, crowding, and cosmic rays raise technical problems. The quality of the derived distances depends further on (variable) internal absorption and the number of available Cepheids in view of the finite width of the instability strip. (An attempt to beat the latter problem by using a PL-color relation is invalid because the underlying assumption of constant slope of the constant-period lines is unrealistic; cf. Saio & Gautschy 1998). Typical errors of individual Cepheid distances from HST are therefore ±0.2 mag (10% in distance). For five of the nine SNe Ia in Table 1 (below) the resulting errors in luminosity are smaller, because they suffer closely the same (small) absorption as “their” Cepheids such that only apparent distance moduli are needed.

3. The Calibration of SNe Ia Luminosities from Cepheid Distances

The HST project for the luminosity calibration of SNe Ia has so far provided Cepheid distances for six galaxies which have produced seven SNe Ia. Their absolute B and V magnitudes at maximum are repeated here in Table 1 from Parodi et al. (1999). The individual errors are compounded from the error of the Cepheid distance and the goodness of the SN light curve; they are listed as well as the original archive sources by Saha et al. (1999). On average the errors amount to 0.22 mag in B and 0.20 in V.

Table 1 contains two additional SNe Ia. A Cepheid distance of NGC 4414 has been published by Turner et al. (1998). The photometric data of the corresponding SN Ia, SN 1974G, have been compiled by Schaefer (1998). SN 1998bu has occurred in NGC 3368, for which a Cepheid distance was already available (Tanvir et al. 1995); the photometry of the SN is excellent (Suntzeff et al. 1998).

The quality of the four reddest SNe Ia in Table 1 is somewhat downgraded by corrections for internal absorption which is clearly present and larger than for the Cepheids in the same galaxy. This affects particularly SN 1974G, SN 1989B, and SN 1998bu. The different sources of the color excesses $E(B-V)$ are given by Saha et al. (1999).

A glance at Table 1 shows that the old SN 1895B was somewhat overluminous. It is omitted in the following mainly because its $V$-magnitude is not known. The scatter in absolute magnitude of the remaining eight SNe Ia amounts to only 0.11, which is considerably less than the estimated individual errors and provides independent proof of SNe Ia being powerful standard candles.

The mean absolute magnitudes at B and V maximum of the eight SNe Ia are shown in Table 1, weighted and unweighted. We adopt in the following

$$M_B(\text{max}) = -19.47 \pm 0.07, \quad \text{and}$$

$$M_V(\text{max}) = -19.48 \pm 0.07. \quad (1)$$

The empirical luminosity calibration is in perfect agreement with presently available theoretical models. Höflich & Khokhlov (1996) have fitted sufficiently blue models, i.e. $(B-V) < 0.2$ at maximum, to the light curves and spectra of 16 SNe Ia. Their mean


| SN     | Galaxy     | $\log v_{220}^{(1)}$ | $m_B^{(5)}$ | $(B - V)^7$ | $M_B$   | $M_V$   | $\Delta m_{15}$ |
|--------|------------|----------------------|------------|------------|---------|---------|----------------|
| 1895B  | NGC 5253  | 2.464$^{(2)}$        | 8.26       | $\cdots$  | -19.87  | $\cdots$| $\cdots$       |
| 1937C  | IC 4182    | 2.519                | 8.83       | -0.05      | -19.53  | -19.48  | 0.87           |
| 1960F  | NGC 4496A | 3.072$^{(3)}$        | 11.60      | 0.06       | -19.56  | -19.62  | $\cdots$      |
| 1972E  | NGC 5253  | 2.464$^{(2)}$        | 8.61       | -0.03      | -19.52  | -19.49  | 0.87           |
| 1974G  | NGC 4414  | 2.820                | 11.82$^{(6)}$ | 0.02  | -19.59  | -19.61  | 1.11           |
| 1981B  | NGC 4536  | 3.072$^{(3)}$        | 11.64$^{(6)}$ | -0.02 | -19.46  | -19.44  | 1.10           |
| 1989B  | NGC 3627  | 2.734                | 10.86$^{(6)}$ | -0.02 | -19.36  | -19.34  | 1.31           |
| 1990N  | NGC 4639  | 3.072$^{(3)}$        | 12.76      | 0.06       | -19.27  | -19.33  | 1.03           |
| 1998bu | NGC 3368  | 2.814$^{(4)}$        | 10.84$^{(6)}$ | -0.02 | -19.53  | -19.51  | 1.01           |

mean (straight), excluding SN 1895B: $-19.48 \pm 0.04$

mean (weighted), excluding SN 1895B: $-19.47 \pm 0.07$

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1) The velocities used are corrected for Virgocentric infall assuming a local infall velocity of 220\,$\text{km}\,\text{s}^{-1}$.  
2) The mean velocity $v_{220} = 291\,$\,$\text{km}\,\text{s}^{-1}$ of the CenA group is used.  
3) The mean velocity $v_{220} = 1179\,$\,$\text{km}\,\text{s}^{-1}$ of the Virgo cluster is used.  
4) The mean velocity $v_{220} = 652\,$\,$\text{km}\,\text{s}^{-1}$ of the Leo group is used.  
5) The sources for the apparent magnitudes, corrected for Galactic absorption, are given by Parodi et al. 1999.  
6) Corrected for additional absorption in the parent galaxy.  
7) Corrected for galactic and internal absorption where applicable.

Luminosity is identical to equations (1) and (2). In a recent review Branch (1998) has concluded that present theory is best satisfied by $M_B \approx M_V = -19.4$ to $-19.5$ for blue SNe Ia.

Della Valle et al. (1998) have attempted to derive an independent distance of NGC 1380, host of SN 1992A, by means of the peak of the luminosity function of globular clusters (GCLF) and advocated a low luminosity of the SN. However, the GCLF method is known to give sometimes erratic results (Tammann 1998b).

Kennicutt, Mould, & Freedman (1998), and Freedman (1999) have discarded several of the calibrators in Table 1 and added two that are not based on direct Cepheid distances to the host galaxy. They have consequently derived a fainter mean absolute $B$ magnitude than equations (1) and (2). Specifically, they assume that the distance of the early-type galaxies NGC 1316 and NGC 1380 in the Fornax cluster, parent galaxies of SN 1980N and SN 1992A, are identical with that of the spiral NGC 1365 for which there is a Cepheid distance. Suntzeff et al. (1998) have also considered the questionable SN 1980N and SN 1992A as possible calibrators.
However, there are reasons to suspect that NGC 1365 is in the foreground of the Fornax cluster and therefore that the precept of the fainter calibration used by Kennicutt et al. (1998), calibrating the two Fornax SNe Ia via NGC 1365, is not correct. The evidence is that Wells et al. (1994) have demonstrated that the multi-color light curves of SN 1989B in NGC 3627 and SN 1980N in NGC 1316 are virtually identical, and in fact establish the reddening and extinction to SN 1989B by comparing the magnitude shifts in different passbands relative to SN 1980N. Asserting then that SN 1980N has the same peak brightness as SN 1989B yields the distance modulus difference of 1.62 ± 0.03 (Wells et al. 1994). There is additional uncertainty of ±0.17 to allow for scatter in the difference in peak brightness of two SNe Ia with the same decline rate (cf. equation (5) below). With the Cepheid modulus of \((m - M)_0 = 30.22 ± 0.12\) (Saha et al. 1999) for SN 1989B, the derived modulus of NGC 1316, host to SN 1980N, is 31.81 ± 0.21 (cf. also Fig. 2 below). This is 0.5 more distant than the Cepheid distance of NGC 1365 (Madore et al. 1998), but is closely the same as found for the early-type galaxies of the Fornax cluster by independent methods (Tammann 1998b). In any case the implication of Kennicutt et al. (1998) and Freedman (1999) that the two twin SNe Ia 1989B and 1980N should differ by 0.5 in luminosity has little credibility.

Some advocates of a high value of \(H_0\) have excluded the brighter calibrators in Table 1 for various arguments. If they are replaced by SN 1980N and SN 1992A, for which no direct Cepheid distances exist, the mean luminosity of blue SNe Ia becomes arbitrarily low (and the value of \(H_0\) equally high).

The \(HST\) project for the luminosity calibration of SNe Ia will be continued. Cepheid observations are presently granted for NGC 4527 (with the peculiar-spectrum and possibly overluminous SN 1991T) and NGC 3982 (with SN 1998aq).

4. SNe Ia Luminosities in Function of Second Parameters

There is a rich literature on distance-independent observables which govern the luminosity of SNe Ia. The original driver was the hope to unify the bright, blue SNe Ia with “Branch-normal” spectra and the faint, red SNe Ia with peculiar spectra. The latter are easily distinguished by the observer and are here excluded a priori, because blue and red SNe Ia may well form a dichotomy (e.g. Nadyozhin 1998). But even for the blue SNe Ia with a total luminosity range of \(\sim 0.6\) it is justified to ask whether their luminosity depends on second parameters.

Indeed it could be established that the luminosity of blue SNe Ia correlates with the decline rate \(\Delta m_{15}\) (or some other measure of the light curve shape), the SN color, and the Hubble type (or color) of the parent galaxy. There must be other more physical parameters like Ni mass, temperature, expansion velocity, or spectral features which correlate with luminosity, but the data are presently too sparse to be useful. An increase of the luminosity scatter with increasing galactocentric distance, proposed by Wang, Höflich, & Wheeler (1997), does not seem to be significant for blue SNe Ia (Parodi et al. 1999).

The difficulty of establishing a SN luminosity - second-parameter correlation is that independently determined luminosities are needed. All known distance indicators with the necessary range, except Cepheids observed with \(HST\), are much too inaccurate for
the purpose. Since only relative luminosities and hence distances are needed, regres
was taken to velocity distances. But even beyond \( v = 1000 \text{ km s}^{-1} \) peculiar motions and a possible “overexpansion” out to 10\,000 \text{ km s}^{-1} (Tammann 1998a, 1999; Zehavi et al. 1998) may affect the luminosities derived from recession velocities. It is safe therefore to concentrate on blue SNe Ia beyond 10\,000 \text{ km s}^{-1}.

The best visualization of how to derive second-parameter correlations is provided by the Hubble diagram of blue SNe Ia (Fig. 1). Here the 54 blue SNe Ia with known \( B \) and \( V \) maxima, are plotted, as compiled by Parodi et al. (1999) from the Tololo/Calan survey (Hamuy et al. 1996b) and other sources. Correlations of the residuals (read in magnitude) from the mean Hubble line with slope 0.2 can now be sought with any second parameters, giving highest weight to SNe Ia with \( v > 10\,000 \text{ km s}^{-1} \) because of non-linearity effects of the expansion field. A detailed analysis is given by Parodi et al. (1999). Here only a brief summary is given.

The 17 SNe Ia with \( v > 10\,000 \text{ km s}^{-1} \) define the Hubble line with forced slope 0.2 as follows

\[
\log v = 0.2m_B + (0.62 \pm 0.01), \quad \sigma_B = 0.18 \quad (3)
\]

\[
\log v = 0.2m_V + (0.63 \pm 0.01), \quad \sigma_V = 0.15. \quad (4)
\]

The small scatter, before any second-parameter correction is applied, should be noted.

The best correlation between the luminosity and the decline rate \( \Delta m_{15} \) is given by the same SNe Ia as (assuming arbitrarily \( H_0 = 55 \))

\[
M_B = -19.56 + 0.62(\Delta m_{15} - 1.1), \quad \sigma_B = 0.17 \quad (5)
\]

\[
M_V = -19.59 + 0.49(\Delta m_{15} - 1.1), \quad \sigma_V = 0.13, \quad (6)
\]

where the scatter is only marginally reduced.

The luminosity-SN color relation, again for the same SNe Ia, is given by

\[
M_B = -19.58 + 1.81(B_{\text{max}} - V_{\text{max}}), \quad \sigma_B = 0.15. \quad (7)
\]

The corresponding equation for \( M_V \) follows trivially by decreasing the slope by one unit.

SN color is apparently somewhat more efficient in reducing the scatter than the decline rate \( \Delta m_{15} \).

In principle the variation in color can be intrinsic to the present sample of SNe Ia or can be caused by absorption in the host galaxy. Riess, Press, & Kirshner (1996), Riess et al. (1998), and Phillips et al. (1999) have argued that absorption is the main cause. However, in that case the slope in equation (7) would have to be close to 4. A definite proof that most of the color variation is in fact intrinsic, which is also expected from all SN models, has been provided by Saha et al. (1999) who have shown that SNe Ia become brighter in \( I \) as \( (B_{\text{max}} - V_{\text{max}}) \) becomes redder, and again brighter in \( V \) and \( I \) as \( (V_{\text{max}} - I_{\text{max}}) \) becomes redder!

The fact that internal absorption plays a relatively minor role in distant SNe Ia, whereas four of the calibrating SNe Ia suffer an appreciable absorption is not as puzzling as it may appear at first sight, because observational selection effects dominate the available samples. The apparent magnitudes of the nearby calibrators are so bright
Fig. 1. (a) The Hubble diagram in $B$ for 54 blue SNe Ia. The data before 1985 are represented with crosses. High-quality SNe Ia after 1985 with $v < 10,000$ km s$^{-1}$ are shown with open circles, the more distant ones with filled circles. The eight calibrating SNe Ia are shown with triangles for comparison. (b) The same in $V$ magnitudes. The fitted lines have slope 0.2 according to equations (3) and (4); they only consider SNe Ia with $v > 10,000$ km s$^{-1}$. – The velocities are corrected for a self-consistent Virgo-centric infall model (Kraan-Korteweg 1986) if $v < 3000$ km s$^{-1}$; for $v > 3000$ km s$^{-1}$ an additional correction was applied for the motion of 630 km s$^{-1}$ relative to the CMB dipole anisotropy (Smoot et al. 1992). – (From Parodi et al. 1999).
that some absorption hardly hampers their discovery. At large distances, however, only the apparently very brightest SNe Ia are discovered, which automatically discriminates against absorption.

Present data do not allow to derive a clear-cut correlation between luminosity and Hubble type T. While the nearer SNe Ia in ellipticals are \( \sim 0.2 \) fainter in E/S0 galaxies than in spirals (note that any absorption correction could only increase the difference), the difference disappears beyond 10000 km s\(^{-1}\). Clearly larger samples are needed. In any case the Hubble type T is strongly correlated with \( \Delta m_{15} \), and once the SN luminosities are corrected for \( \Delta m_{15} \) and color no significant correlation with T remains.

If the 17 most distant SNe Ia of the sample are reduced to \( \Delta m_{15} = 1.1 \) and \( (B_{\text{max}} - V_{\text{max}}) = 0.00 \) by means of equations (5)–(7) one obtains a corrected Hubble line of form

\[
\log v = 0.2m_{\text{corr}}^B + (0.656 \pm 0.005), \quad \sigma_B = 0.12. \tag{8}
\]

Here the small scatter is close to what can be expected from the observational errors in \( m_B, m_V \), and \( \Delta m_{15} \). Any additional reduction of the scatter would therefore be artificial. (The two-step procedure to correct first for \( \Delta m_{15} \) and then for color is statistically not correct. However, \( \Delta m_{15} \) and color are so weakly correlated that a simultaneous solution gives exactly the same result [cf. Parodi et al. 1999]).

5. Conclusions

The most interesting conclusion for the physicist is that the empirical luminosity calibration of SNe Ia is in very good agreement with the results of present model calculations.

The cosmologist must be pleased that uncorrected blue SNe Ia have a luminosity scatter of only \( \sigma_B = 0.18 \) and \( \sigma_V = 0.15 \) (and even less in I). After correction for \( \Delta m_{15} \) (or any similar light curve shape parameter) and color the scatter is reduced to \( \sigma_B = 0.12 \), which might entirely be caused by observational errors. It is not likely that the Universe will ever offer better standard candles.

For the astronomer blue SNe Ia provide an unparalleled tool for the derivation of individual galaxy distances and of the large-scale value of \( H_0 \).

Equations (3) and (4) can easily be transformed into

\[
\log H_0(B) = 0.2M_B + (5.62 \pm 0.01), \quad \text{and} \tag{9}
\]

\[
\log H_0(V) = 0.2M_V + (5.63 \pm 0.01). \tag{10}
\]

Inserting the absolute magnitudes from equations (1) and (2) immediately yields

\[
H_0(B) = 53.2 \pm 2.0 \quad \text{(internal error)}, \tag{11}
\]

\[
H_0(V) = 54.2 \pm 2.0 \quad \text{(internal error)}. \tag{12}
\]

This value holds for SNe Ia beyond 10000 km s\(^{-1}\).

Correspondingly the SNe Ia corrected for \( \Delta m_{15} \) and color give from equation (8)

\[
\log H_0(B, V) = 0.2M_{\text{corr}}^B + (5.656 \pm 0.015). \tag{13}
\]
The $B$ and $V$ magnitudes lead to the same relation by construction because they are reduced to $(B_{\text{max}} - V_{\text{max}}) = 0.00$. If the analogue corrections (from equations (5)–(7)) are applied to the seven calibrators in Table 1 with known $\Delta m_{15}$, one obtains

$$M_{B}^{\text{corr}} = -19.44 \pm 0.04,$$

and from a combination of equations (13) and (14)

$$H_{0}(\text{cosmic}) = 58.6 \pm 1.2 \quad \text{(internal error)}.$$

The value of $H_{0}$ after correction for $\Delta m_{15}$ and color is 9% larger than without these corrections. The reason is that the local calibrators are somewhat slower decliners ($\delta \Delta m_{15} = 0.29$) and somewhat bluer ($\delta (B - V) = 0.04$) than the distant SNe Ia. This in turn is caused by the requirement that the calibrators have to be in spirals (with Cepheids) while the distant objects come in galaxies of all kinds of Hubble types.

The 17 high-quality SNe Ia inside $10\,000$ km s$^{-1}$ give a value of $H_{0}$ which is $2 - 3$ units larger. This is a reflection of the suspected low-density bubble of corresponding size.

An alternate route to $H_{0}$ is via the Virgo cluster (Fig. 2). Four well observed SNe Ia (excluding the unusual object 1991T) are known in the Virgo cluster. They give $m_{B}^{\text{corr}} = 12.11 \pm 0.15$ and with equation (14) $(m - M)_{\text{Virgo}} = 31.55 \pm 0.16$. A miniature Hubble diagram plotting recession velocities versus relative cluster distances out to $11\,000$ km s$^{-1}$ is shown in Fig. 2 (cf. e.g. Tamman 1997; Fig. 4 gives a full-size Hubble diagram of the relative cluster distances). These relative distances are much more secure than absolute distances and define the Hubble line with very small scatter, i.e.

$$\log v = 0.2 [(m - M)_{\text{Cluster}} - (m - M)_{\text{Virgo}}] + (3.070 \pm 0.024).$$

From equation (16) follows

$$H_{0} = -0.2 (m - M)_{\text{Virgo}} + (8.070 \pm 0.024).$$

If the above Virgo cluster modulus from SNe Ia is inserted, one finds $H_{0} = 58 \pm 6$ at a distance of $\sim 10\,000$ km s$^{-1}$, fully consistent with equation (15).

The three SNe Ia in the Fornax cluster provide also a good distance to this cluster (cf. Fig. 2). However, it is not useful for the determination of $H_{0}$ because the observed mean cluster velocity may be affected by unknown peculiar motions of up to $\pm 20\%$.

Some authors have derived higher values of $H_{0}$ from SNe Ia. These values can be constructed by (i) excluding arbitrarily the brighter calibrators in Table 1, (ii) interpreting falsely the intrinsic color variations of SNe Ia as an effect of absorption, and (iii) adding “calibrators” for which no direct and reliable distance determinations are available.

The conclusion is that SNe Ia require $H_{0} = 59$ in perfect agreement with all independent evidence (cf. Theureau & Tammann 1998). The internal error is almost vanishingly small. The systematic error depends on the adopted LMC modulus ($< 0^m1$), the zero-point error of the HST photometry ($< 0^m1$), uncertainties of the absorption corrections of the calibrators and distant SNe Ia ($< 0^m1$), and future improvements of the second-parameter corrections ($< 0^m1$). It is highly unlikely that these effects together will affect $H_{0}$ by more than 10%. The 95% confidence range is therefore $54 \leq H_{0} < 64$. 

9
Fig. 1

\[ H_0 = 59 \pm 2 \]
SNe Ia out to 30 000 km s\(^{-1}\)

\[ H_0 = 58 \pm 6 \]
Clusters out to 10 000 km s\(^{-1}\)

\( \odot \)

Fig. 2. The distance scale built only on SNe Ia.
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