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HIPPARCOS calibration of the peak brightness of four SNe Ia and the value of H_0

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Abstract. HIPPARCOS geometrical parallaxes allowed us to calibrate the Cepheid Period-Luminosity relation and to compute the true distance moduli of 17 galaxies. Among these 17 galaxies, we selected those which generated type Ia Supernovae (SNe Ia). We found NGC 5253, parent galaxy of 1895B and 1972E, IC 4182 and NGC 4536 parents of 1937C and 1981B, respectively.

We used the available B-band photometry to determine the peak brightness of these four SNe Ia. We obtained $\langle M_B(MAX)\rangle = -19.65 \pm 0.09$. Then, we built a sample of 57 SNe Ia in order to plot the Hubble diagram and determine its zero-point. Our result ($ZP_B = -3.16 \pm 0.10$) is in agreement with other determinations and allows us to derive the following Hubble constant: $H_0 = 50 \pm 3$ $(internal)$ $km.s^{-1}.Mpc^{-1}$.

Key words: supernovae: general – distance scale

1. Introduction

A Supernova represents a sudden brightening of a star by about 20 magnitudes. These events have very bright absolute maximum magnitudes which allow us to detect them up to cosmological distances. Moreover, in the light of our knowledge of spectral type Ia Supernovae, their peak brightness are supposed to have a small dispersion, thus they are less sensitive to Malmquist bias, and SNe are supposed to be not significantly affected by peculiar motions (because they are situated remote enough to make the corrections from the Virgo infall less uncertain). One early proof was produced when Kowal (1968) plotted the Hubble diagram (m_{MAX} vs redshift) for some SNe Ia and highlighted its small dispersion and its linearity. Many studies claimed that the intrinsic dispersion may be less than 0.3 mag (assuming the exclusion of some abnormals events).

Type Ia Supernovae are thus considered to be excellent cosmological distance indicators (“standard candles”) and provide us a very useful tool to estimate the Hubble constant, as long we can independently calculate their absolute magnitude.

Our present goal is to calibrate the maximum peak brightness of SNe Ia thanks to a previous work where we have determined the distance moduli of 17 galaxies based on the geometrical calibration of the Cepheid Period-Luminosity relation. We checked those which have generated a SN Ia and found only three galaxies lodging four SNe Ia: 1895B and 1972E in NGC 5253, 1937C in IC 4182 and 1981B in NGC 4536. Then using both the three galactic distance moduli and the B-band photometry (as homogeneous as possible) of the four SNe Ia, we are able to compute the mean absolute magnitudes at maximum.

We make a selection from among a large sample of distant SNe Ia to build a reliable sample and plot a Hubble diagram whose zero-point is computed. We finally use both the peak brightness and the zero-point values to derive the Hubble constant.

2. The parent galaxies

The data presented in this section are summarized in Table 1.

2.1. The distance moduli

We use in the present paper the results of a previous work (Paturel et al., 1997a) where new distance moduli were obtained for 17 calibrating galaxies. In order to derive this moduli, we have defined a new calibration of the Period-Luminosity relation (independently of previous determinations) from new geometrical parallaxes of galactic Cepheids obtained with the HIPPARCOS satellite. This new calibration was combined with a compilation of extragalactic Cepheid measurements in the BVRI photometric system.

The external error of the new zero-point is about 0.25 mag in absolute magnitude. Considering that this error is much larger than the others when computing the distance moduli ($\sigma_m, \sigma_{\log P}$, etc...), we will assume that the external error on the moduli is about 0.30 mag. Even though the precision of this result is poor, its accuracy (the measure of how close the result is to the true value) is quite acceptable.

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In the following, we will quote the external errors along with the external errors in order to appreciate the effect of both error sources, and we will compute both the internal and the external error on the Hubble constant.

2.2. NGC 5253

NGC 5253 is the host galaxy of 1895B and 1972E. According to our previous results based on the HIPPARCOS geometrical calibration (Paturel et al., 1997a) we assign to this galaxy a true distance modulus:

$$\mu = (m - M)_0 = 27.96 \pm 0.05 \; (internal)$$

According to Burstein & Heiles (1984), the B-band galactic extinction in its direction is $A_g = 0.20$. The morphology is uncertain but it is probably a spiral (morphological type code 7-8 according to the LEDA database) and corresponds to a kind of S type. It's a galaxy whose total color is $(B - V)_T^0 = 0.26$ (de Vaucouleurs et al., 1991).

2.3. IC 4182

IC 4182 is the parent galaxy of 1937C. It is a Sm type galaxy (morphological type code 8-9), and the B-band galactic extinction in its direction (A_g) is negligible. Its true distance modulus is supposed to be:

$$\mu = 28.50 \pm 0.03 \; (internal)$$

2.4. NGC 4536

NGC 4536 is the parent of the more recent SN, 1981B. Its morphological type is SBbc (morphological type code = 4), and the B-band galactic extinction in its direction (A_g) is negligible too. We assign to it a true distance modulus:

$$\mu = 31.18 \pm 0.03 \; (internal)$$

Its total color $(B - V)_T^0$ equals 0.47.

3. Supernovae Ia photometry

3.1. 1895B

The discovery was made by Miss Fleming on 1895 July 8, at Arequipa (Fleming & Pickering, 1896). The star was located 23 arcsec North of NGC 5253. The light curve was plotted later by Hubble & Lundmark (1922) using subsequent observations made at Harvard observatory. Walker (1923) put the observations on a revised m_{pg} scale and derived m_{pg}(max) = 8.0. However Leibundgut et al. (1991) fitted a type Ia template to the light curve (even though only loose constraints can be placed on it) and obtained m_{pg}(max) = 7.03 (removing their extinction A_{pg} = 0.13). However some evidences can explain that this result is wrong (see Saha et al., 1995, for details) and that $m_{pg}(max) = 8.05 \pm 0.17$ seems to be a good compromise solution.

Following the m_{pg} tranformation to B system of Arp (1961), and assuming $(B - V)_{B(max)}$ = +0.09 (Sandage & Tammann, 1993) we finally obtain:

$$B(max) = 8.33 \pm 0.20$$

Schaefer & Bradley (1995) scanned the old SN plates and derived $B(max) = 8.26 \pm 0.11$ using the most likely shape, which is consistent with the previous value (note that they placed conditions on a firm limit on the peak magnitude $B(max) < 8.49 \pm 0.03$).

However their result may appear to be unreliable due to the age of the observations and to the many transformations needed.

We can now calculate the peak absolute magnitude which is simply:

$$\begin{aligned} M_B(MAX) &= B(max) - \mu - A_g \\ &= -19.83 \pm 0.23 \; (internal) \qquad (1) \\ &= -19.83 \pm 0.37 \; (external) \end{aligned}$$

where A_g is the B extinction according to Burstein & Heiles (1984).

3.2. 1972E

The discovery was made by Kowal on 1972 May 13 (Kowal, 1972), the observations began on May 17 at the European Southern Observatory in Chile and were conducted by Ardeberg & de Groot (1973). 1972E was located 56 arcsec West and 85 arcsec South of the nucleus of NGC 5253. It appeared to be a prototype of SNe Ia and was actually used to define the type Ia. Leibundgut et al. (1991) fitted a type Ia template to the well constrained light curve, and obtained (removing their extinction A_B = 0.13):

$$B(max) = 8.58 \pm 0.10$$

So that we obtain:

$$\begin{aligned} M_B(MAX) &= -19.58 \pm 0.15 \; (internal) \qquad (2) \\ &= -19.58 \pm 0.33 \; (external) \end{aligned}$$

3.3. 1937C

The discovery was made by Baade & Zwicky (1938). The photographic photometry was made on Palomar Mountain and was very accurate. 1937C is also a prototype a SNe Ia like 1972E. The Leibundgut et al. (1991) fit seems very reliable and results in $m_{pg}(max) = 8.50 \pm 0.05$ (removing their extinction A_B = 0.13). Assuming the same transformation as before (Arp, 1961) with $(B - V)_{B(max)} = +0.19 \pm 0.15$ (Saha et al., 1994), a further correction of 0.07 mag is required because this photometry produces brighter results than the photoelectric one (Saha et al., 1994), leading us to:

$$B(max) = 8.83 \pm 0.11$$

And:

$$\begin{aligned} M_B(MAX) &= -19.67 \pm 0.15 \; (internal) \qquad (3) \\ &= -19.67 \pm 0.33 \; (external) \end{aligned}$$

Table 1. Host galaxy information.

R.A. 2000 DEC. h mn s deg ’ ”	Name	Type	Ag	SN Ia	μ
133955.8 − 313841	NGC5253	S?	0.20	1895B, 1972E	27.96±0.05
130549.3 + 373621	IC4182	Sm	0.00	1937C	28.50±0.03
123426.9 + 021119	NGC4536	SBbc	0.00	1981B	31.18±0.03

3.4. 1981B

On 1981 March 2, Tsvetkov discovered a 12th magnitude SN Ia (Aksenov, 1981) located 36 arcsec east and 36 arcsec north of the nucleus of NGC 4536. The light curve is very well constrained and the Leibundgut et al. fit (in agreement with Phillips, 1993, and Schaefer, 1995) leads to $B(max) = 12.00 \pm 0.10$, and then: $M_B(MAX) = -19.18 \pm 0.14$.

Although this SN seems obviously to be less luminous than the three others, all studies considered it as a completely normal event. The recent revised results from Patat et al. (1997) suggest the value $B(max) = 11.74$. Such a result would lead to $M_B(MAX) = -19.44$.

However we may also consider some evidence of a certain color excess of about $E_{B-V} \simeq 0.10 \pm 0.05$ (Branch et al., 1983, Buta & Turner, 1983, Saha et al., 1996) even though it is not well constrained. Burstein & Heiles claimed A_g is negligible for NGC 4536, but 1981B may be extinguished inside its host galaxy contrary to 1937C which has no color excess. We would then obtain $A_B \simeq 0.41$ (with a ratio of total to selective absorption of 4.1 for the photometric B-band, Savage & Mathis, 1979), and finally from the dereddened magnitude:

$$\begin{aligned} M_B(MAX) &= -19.59 \pm 0.23 \; (internal) \qquad (4) \\ &= -19.59 \pm 0.38 \; (external) \end{aligned}$$

in better agreement with previous determinations.

3.5. The mean value

From Eqs. 2 to 5, assuming:

$$\sigma = \frac{1}{\sqrt{\sum \frac{1}{\sigma_i^2}}}$$

the peak brightness weighted mean value[1] of our four SNe Ia is:

$$\begin{aligned} \langle M_B(MAX) \rangle &= -19.65 \pm 0.09 \; (internal) \qquad (5) \\ &= -19.66 \pm 0.18 \; (external) \qquad (6) \end{aligned}$$

We could compute this mean value using only part of the data, because one can argue that some are less reliable. However it would not change significantly the result because the four values are quite slightly scattered and the computed mean is very close to the more reliable values (we would obtain $\langle M_B(MAX) \rangle = -19.62 \pm 0.11$ using only 1937C and 1972E).

4. The Hubble diagram and H_0

4.1. The data

We needed a database of Supernovae to construct our Hubble diagram: we used the update version (online version, http://athena.pd.astro.it/∼supern/snean.txt) of the Supernovae Asiago Catalogue (Barbon et al., 1989), which contains 1130 Supernovae at the moment, from 1885 to 1997.

First of all, we selected the type Ia according to this catalogue and we removed those without B-band photometry and with unidentified host galaxies. Then we used the Lyon-Meudon Extragalactic Database (LEDA, http://www-obs.univ-lyon1.fr/leda/leda-consult.html) in order to find the radial velocity of each host galaxy and the galactic extinction in the B-band from Burstein & Heiles. We selected the velocities corrected from the infall of the Local Group towards Virgo (v_{Vir}) according to Paturel et al. (1997b), where the chosen infall velocity of the Local Group is 170 $km.s^{-1}$ (Sandage & Tammann, 1990). This last step removed some more SNe Ia whose parent galaxies had no velocity measurements or no galactic extinction (two occurences). It appears that the SN 1963I type may be uncertain. Following Leibundgut & Tammann (1990), we excluded it because there is no evidence available of its classification as type Ia SNe.

We then checked the 57 remaining SNe Ia in order to estimate the errors on the maximum magnitudes. We assign a typical uncertainty of 0.14 mag to the best extinction corrected magnitudes, taking into account both the measurement itself ($\sigma = 0.1$) and the extinction correction ($\sigma = 0.1$). This uncertainty concerns 37 SNe Ia (plus 1972E).

We found three no “Branch normal” SNe Ia in our sample (Branch & Miller, 1993, Branch et al., 1996). Although they are normal events, 1937D, 1963P and 1989B suffered high extinction in their parent galaxies. We assigned an error of one magnitude to 1937D and 1963P while we used the color excess of 1989B ($E(B-V) = 0.37 \pm 0.03$, see Branch et al., 1996) in order to correct its magnitude from total extinction (galactic plus parent-galaxy). The resulting uncertainty on $m_B^{cor.}$ is 0.16 mag.

We also flaged 1971I which has spectral and light-curve particularities ($\sigma_{m_B^{cor.}} = 1.00$), and 1961H which may be overluminous ($\sigma_{m_B^{cor.}} = 0.22$). 1963J and 1983U (Tammann & Sandage, 1995), and 1968E (Patat et al., 1997) have very uncertain light curves so that we assigned to them $\sigma_{m_B^{cor.}} = 1.00$.

We assigned to 1993af an error $\sigma_{m_B^{cor.}} = 3.00$ because its spectra showed that it had been caught several weeks (or

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[1] The weight is taken as the inverse of the square of individual standard error

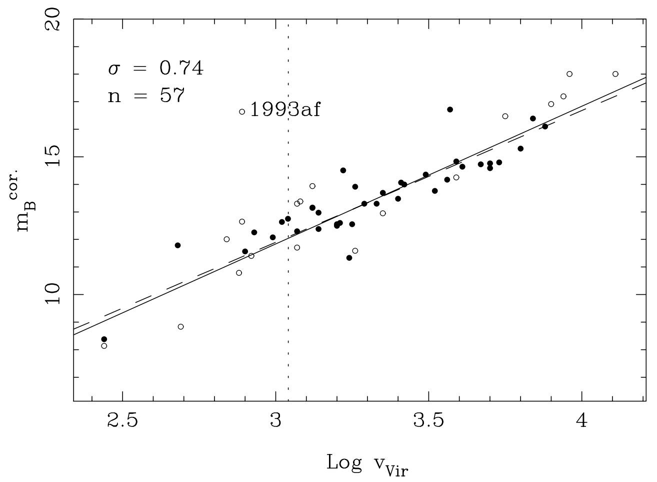

Fig. 1. Hubble diagram obtained from our sample. The dashed line represents the best linear fit to a straight line. The continuous line represents the best fit, forcing the slope to be the theoretical one. The vertical dotted line represents the cut in radial velocities to keep those greater than 1100 $km.s^{-1}$. The filled circles are used for the more confident SNe Ia, whereas open circles describe SNe whose magnitudes are less reliable.

months) after maximum luminosity, so that a reliable photometry was not available (Hamuy et al., 1996b).

At last, among our 57 SNe, 7 others have a flag in the catalogue itself because their real maximum peak brightness may be "brighter than or equal to" the plotted magnitudes. These magnitudes refer usually to discovery which often occured after the peak brightness so that $\sigma_{m_B^{cor.}} = 0.60$.

The photometry carried out at Asiago observatory during the seventies is corrected from errors according to Patat et al (1997); this improvement concerns 1957B, 1960F, 1960R, 1965I, 1970J, 1975N, and Tsvetkov measurements (see also Patat et al., 1997), 1969C, 1971L, 1973N, 1974G and 1974J.

We also checked both the total $(B-V)_T^0$ color of the galaxies (from LEDA, according to de Vaucouleurs et al., 1991) to take into account a possible correlation between color and magnitude peak brightness (Branch et al., 1996), and the morphological types to sort out the elliptical galaxies.

We thus obtained a sample of 57 SNe Ia presented in Table 2 that allows us to plot a Hubble diagram (Fig. 1).

4.2. Analysis

If we consider a linear expansion model, the Hubble diagram will be best fitted by the law:

$$m_B^{cor.} = 5 \log v_{Vir} + ZP_B \tag{7}$$

The uncertainties on $\log v_{Vir}$ are small enough (less than a few hundreths) to satisfy the following condition:

$$5\ \sigma_{\log v_{Vir}} = \frac{5}{\ln 10} \frac{\sigma_{v_{Vir}}}{v_{Vir}} \ll \sigma_{m_B^{cor.}}$$

which allows us to use a direct regression.

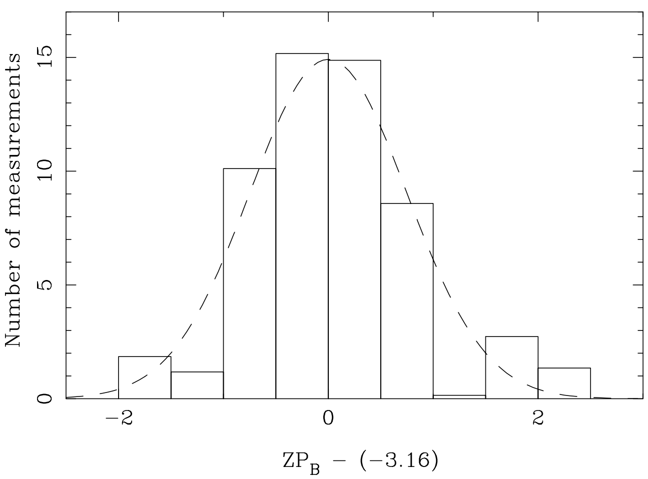

Fig. 2. Histogram of the weighted difference $(ZP_B - (-3.16))$. The dashed Gaussian curve was calculated from the mean and standard deviation estimated from these measurements. The ZP_B obtained from SN 1993af was excluded from this figure.

If we then use weighted measurements of our sample of 57 SNe Ia (the weight being defined as $1/\sigma^2_{m_B^{cor.}}$), we obtain from a maximum likelihood method:

$$\begin{aligned} m_B^{cor.} &= (4.779 \pm 0.064) \log v_{Vir} + (-2.44 \pm 0.21) \\ \sigma &= 0.74 \end{aligned} \tag{8}$$

A Student's t-test on the slope leads to:

$$t = \frac{|4.779 - 5|}{0.064} = 3.45 \tag{9}$$

which is smaller than $t_{0.01}$ (the probability of error is much lower than 0.01). We conclude that the slope is not significantly different from the theoretical one at this probability level.

Then forcing the slope to be exactly 5, we obtain:

$$ZP_B = -3.16 \pm 0.10 \tag{10}$$

In order to test if the distribution is normal, we plot the weighted histogram of the difference $(ZP_B - (-3.16))$ (see Fig. 2). We perform a χ^2 test for this distribution and we obtain $\chi^2 = 1.84$. Referring to a χ^2 table, we observe that, for 8 degrees of freedom, the probability of obtaining in repeated experiments a greater value of χ^2 is $\sim 8\%$, so that we can consider this distribution to be Gaussian ($< ZP_B - (-3.16) >= 0, \sigma = 0.74$).

If we sort out the SNe in our sample according to the nature of their parent galaxy (elliptical or not), it comes down to excluding five events that occured in elliptical galaxies (only 1939A, 1957B, 1961H, 1970J and 1994M because 91% of our sample is made of SNe Ia that occured in spiral galaxies) and we arrive at the same value of ZP_B within about three hundreths ($ZP_B = -3.20 \pm 0.11$).

At last, we can sort out the sample according to the total color of the parent galaxy $(B-V)_T^0$. If we keep only those with $(B-V)_T^0 \leq 0.75$, we obtain $ZP_B = -3.37 \pm 0.15 (n = 25)$.

Table 2. Sample of 57 Supernovae of type Ia. *Column 1*: SNe name. *Column 2*: Parent galaxy name. *Column 3*: Equatorial coordinates for equinoxe 2000 of parents galaxies. *Column 4*: Parent galaxy morphological type. *Column 5*: *Log*$_{10}$ of the radial velocity corrected from the Virgo infall. *Column 6 and 7*: Apparent B magnitude corrected for extinction and the associated uncertainty. The flag (!) means that the value has been modified from the Asiago catalogue value. *Column 8*: Galactic extinction (B-band) according to Burstein & Heiles (1984). We don't list A_g for NGC 3627, because we calculated the galactic extinction from the color excess.

SNe Ia	Galaxy	R. A. 2000 DEC. h mn s deg ’ ”	Type	log v_{Vir}	$m_B^{cor.}$	$\sigma_{m_B^{cor.}}$	A_g
1895 B	NGC5253	133955.8 − 313841	Sd	2.436	8.13!	0.22	.20
1937 C	IC4182	130549.3 + 373621	Sm	2.688	8.83!	0.15	.00
1937 D	NGC1003	023916.5 + 405222	Sc	2.891	12.65	1.00	.25
1939 A	NGC4636	124249.8 + 024117	E	3.037	12.75	0.14	.05
1957 B	NGC4374	122503.7 + 125315	E	2.988	12.07!	0.14	.13
1960 F	NGC4496A	123139.8 + 035621	SBd	3.241	11.33!	0.14	.01
1960 R	NGC4382	122524.6 + 181127	SO-a	2.903	11.57!	0.14	.03
1961 H	NGC4564	123627.0 + 112621	E	3.069	11.71	0.22	.09
1963 J	NGC3913	115038.9 + 552112	Scd	3.067	13.30	1.00	.00
1963 P	NGC1084	024559.7 − 073442	Sc	3.124	13.94	1.00	.06
1965 I	NGC4753	125222.7 − 011157	SO	3.060	12.37!	0.14	.03
1966 J	NGC3198	101954.9 + 453309	SBc	2.916	11.40	0.60	.00
1967 C	NGC3389	104827.8 + 123201	Sc	3.121	13.14	0.14	.06
1968 E	NGC2713	085720.6 + 025521	SBab	3.587	14.25	1.00	.15
1969 C	NGC3811	114116.2 + 474135	SBc	3.517	13.77!	0.14	.02
1970 J	NGC7619	232014.7 + 081223	E	3.588	14.83!	0.14	.17
1971 I	NGC5055	131549.2 + 420206	Sbc	2.841	12.00	1.00	.00
1971 L	NGC6384	173224.5 + 070338	SBbc	3.247	12.56!	0.14	.44
1972 E	NGC5253	133955.8 − 313841	Sd	2.436	8.38!	0.14	.20
1973 N	NGC7495	230857.3 + 120254	Sc	3.697	14.76!	0.14	.15
1974 G	NGC4414	122627.5 + 311329	Sc	2.931	12.26!	0.14	.02
1974 J	NGC7343	223837.5 + 340423	SBbc	3.884	15.30!	0.14	.30
1975 A	NGC2207	061622.0 − 212221	SBbc	3.410	14.07	0.14	.53
1975 N	NGC7723	233857.0 − 125742	SBb	3.262	13.91!	0.14	.09
1978 E	MCG+06-49-36	223459.9 + 371157	Sc	3.704	14.59	0.14	.61
1979 B	NGC3913	115038.9 + 552112	Scd	3.067	12.30	0.14	.00
1980 N	NGC1316	032241.5 − 371228	SO	3.200	12.50	0.14	.00
1981 B	NGC4536	123426.9 + 021119	SBbc	3.257	11.59!	0.23	.00
1982 B	NGC2268	071415.6 + 842250	SBbc	3.396	13.48	0.14	.22
1982 W	NGC5485	140711.5 + 550008	SO	3.221	14.50	0.14	.00
1983 G	NGC4753	125222.7 − 011157	SO	3.060	12.97	0.14	.03
1983 R	IC1731	015012.7 + 271149	SBc	3.557	14.17	0.14	.23
1983 U	NGC3227	102331.4 + 195148	SBa	3.080	13.38	1.00	.02
1983 W	NGC3625	112031.7 + 574655	SBb	3.333	13.30	0.14	.00
1986 A	NGC3367	104634.5 + 134509	SBc	3.486	14.35	0.14	.05
1987 D	MCG+00-32-01	121940.5 + 020451	Sbc	3.346	13.70	0.14	.00
1987 N	NGC7606	231904.8 − 082908	Sb	3.347	12.95	0.60	.05
1988 F	MCG+02-37-15a	142858.6 + 135142	SO	3.730	14.80	0.14	.00
1989 A	NGC3687	112800.6 + 293041	SBbc	3.419	14.00	0.14	.00
1989 B	NGC3627	112014.4 + 125942	SBb	2.880	10.78!	0.16	
1989 M	NGC4579	123744.1 + 114911	SBb	3.196	12.55	0.14	.15
1990 N	NGC4639	124252.6 + 131530	SBbc	3.024	12.64	0.14	.06
1991 ag	IC4919	200009.2 − 552228	SBd	3.611	14.64	0.14	.16
1991 bb	UGC2892	035337.6 + 190616	SBbc	3.903	16.91	0.60	.79
1992 A	NGC1380	033626.9 − 345833	SO	3.215	12.60	0.14	.00
1992 P	IC3690	124249.5 + 102134	Sbc	3.884	16.10	0.14	.00
1992 ap	UGC10430	163033.2 + 412936	SBbc	3.964	18.00	0.60	.00
1993 I	MCG+2-32-144	123443.0 + 090011	SO	4.111	18.00	0.60	.00
1993 ae	UGC1071	012944.8 − 015832		3.754	16.47	0.60	.13
1993 af	NGC1808	050742.7 − 373051	SBa	2.891	16.63	3.00	.07
1993 ah	ESO471-27	235150.7 − 275748	SO	3.943	17.20	0.60	.00

Table 2. (continued)

SNe Ia	Galaxy	R. A. 2000 DEC. h mn s deg ' "	Type	$\log v_{Vir}$	$m_B^{cor.}$	$\sigma_{m_B^{cor.}}$	A_g
1994 D	NGC4526	123402.9 + 074201	SO	2.682	11.79	0.14	.01
1994 M	NGC4493	123108.5 + 003648	E	3.841	16.39	0.14	.01
1994 S	NGC4495	123123.1 + 290813	Sab	3.670	14.73	0.14	.07
1994 ae	NGC3370	104703.6 + 171626	Sc	3.122	13.16	0.14	.04
1995 D	NGC2962	094054.0 + 051000	SO-a	3.286	13.30	0.14	.10
1995 E	NGC2441	075154.6 + 730058	SBb	3.569	16.71	0.14	.09

The 13 remaining SNe Ia, with $(B-V)_T^0 \geq 0.75$, leading us to $ZP_B = -2.83 \pm 0.21$ (note that 19 galaxies have no measurement available). These two results tend to show that SNe Ia in redder galaxies have lower luminosities in agreement with Branch et al. results (1996), but following these authors, we won't take this effect further into account when we will compute the Hubble constant.

If we only keep the velocities above 1100 $km.s^{-1}$ to minimize the particular motions among the 57 previous SNe, we obtain a sample of 44 SNe Ia (note that none of the velocity are high enough to justify a departure from linearity in Hubble's law) and: $ZP_B = -3.19 \pm 0.11$. This result does not differ significantly from the main value.

4.3. The value of H_0

Let us now recall the relation:

$$m - M = 5 \log d_{Mpc} + 25 \qquad (11)$$

From Eqs. 7, 11 and the Hubble approximation $H_0 \approx v_{Vir}/d_{Mpc}$ we obtain:

$$\log H_0 = 0.2\langle M_B(MAX)\rangle + 5 - 0.2\ ZP_B \qquad (12)$$

If we then use the best value $ZP_B = -3.16 \pm 0.10$ (Eq. 10) and $\langle M_B(MAX)\rangle = -19.65 \pm 0.09$ (Eq. 5), it leads us to (assuming $\sigma_{H_0} = H_0\ \ln 10\ \sigma_{\log H_0}$):

$$H_0 = 50 \pm 3\ (internal)\ km.s^{-1}.Mpc^{-1} \qquad (13)$$

If we consider the external errors, that is especially $\langle M_B(MAX)\rangle = -19.66 \pm 0.18$ (Eq. 6), we obtain:

$$H_0 = 50 \pm 5\ (external)\ km.s^{-1}.Mpc^{-1} \qquad (14)$$

We have to keep in mind that our present goal is mainly to recalibrate the maximum peak brightness thanks to the HIPPARCOS data, and not to build a new Hubble diagram. Thus we can also use other diagrams such as presented by Saha et al. (1997), and recalibrate it thanks to our new peak calibration. Using their zero-point $ZP_B = -3.265 \pm 0.045$, we would obtain $H_0 = 53 \pm 2\ (internal)\ km.s^{-1}.Mpc^{-1}$.

The same application to the Tammann & Sandage's diagram (1995) with their $ZP_B = -3.186 \pm 0.054$ leads to $H_0 = 51 \pm 2\ (internal)\ km.s^{-1}.Mpc^{-1}$.

Table 3. Dependance of H_0 on our choices (couples ($\langle M_B(MAX)\rangle$, ZP_B)). (1) This paper. (2) Saha et al., 1997. (3) Tammann & Sandage, 1995. (4) Hamuy et al., 1996a. (a) Main weighted value from the four calibrators. (b) Value obtained from 1937C and 1972E only.

	-3.16 (1)	-3.265 (2)	-3.186 (3)	-3.177 (4)	-3.318 (4)
-19.65 (a)	50	53	51	51	54
-19.62 (b)	51	54	52	51	55

At last, using the value $ZP_B = -3.177 \pm 0.029$ from Hamuy et al. (1996a), we compute $H_0 = 51 \pm 2\ (internal)\ km.s^{-1}.Mpc^{-1}$ (and taking into account their absolute magnitude-decline rate relation, we derive from: $H_0 = 54 \pm 2\ km.s^{-1}.Mpc^{-1}$).

Note that the external errors in the three previous applications are about 4 $km.s^{-1}.Mpc^{-1}$.

Table 3 puts together the various results we computed. It obviously appears that these results depend very slightly on the choices we made.

5. Conclusion

The main observation is that the calibration from HIPPARCOS data favors the so called "long distance scale", and is in great agreement with Saha and coworkers's who obtained $H_0 = 58^{+7}_{-8}\ km.s^{-1}.Mpc^{-1}$ in their last paper (1997).

We could also consider the effect of the decline rate (Δm_{15}) on the absolute magnitude and, therefore, on H_0 (Phillips, 1993). However this effect seems to be not yet well determined, and would however increase H_0 by less than 10% (Saha et al., 1997), even if we take into account others effect such as SNe Ia color or Hubble type of the parent galaxy.

We also note that the present work confirms another result based on the same HIPPARCOS calibration (Paturel et al., 1997c), where we obtained $H_0 = 53^{+7}_{-8}\ km.s^{-1}.Mpc^{-1}$ through a completely independent way.

We must add that, although a part of the statistical bias on calibrating distance moduli was corrected, the present moduli could still be affected by a residual bias (Paturel et al., 1997a). In that case, the correction needed would induce a lower value for H_0.

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