Hubble constant from sosie galaxies and HIPPARCOS geometrical calibration

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Abstract. New distances, larger than previous ones, have been obtained for M 31 and M 81 based on the geometrical zero-point of the Cepheid Period-luminosity relation provided by the HIPPARCOS satellite. By combining them with independent determinations we define reasonable ranges for the distances of these important calibrating galaxies.

On this basis, we determine the Hubble constant from the method of sosies (look-alike) galaxies, galaxies having the same characteristics than the calibrators. The method is quite secure because it is purely differential and it does not depend on any assumption (apart from the natural one that two sosies galaxies have similar absolute luminosities). Nevertheless, the Malmquist bias has to be taken into account. The observations behave exactly as predicted from the analytical formulation of the bias. Thus, rejecting galaxies which are affected by the Malmquist bias we derive the Hubble constant:

\[ H_0 = 60 \pm 10 \text{(external)} \text{km.s}^{-1} \text{Mpc}^{-1} \]

If we strictly use the calibration obtained with HIPPARCOS and if the bias found in the Period-Luminosity Relation is considered, the Hubble constant is smaller than this (\( \approx 55 \text{km.s}^{-1} \text{Mpc}^{-1} \)). This gives arguments in favour of the long-distance scale. We briefly discuss possible improvements aiming at still reducing the uncertainty.

Key words: Galaxies:general Galaxies:distances and redshifts Cosmology:distance scale Astronomical data bases: miscellaneous Methods: data analysis Methods: statistical

1. Introduction

From recent measurements with HIPPARCOS astrometric satellite we have obtained new distances for 17 nearby galaxies on the basis of Cepheid geometrical parallaxes (Paturel et al., 1997). This provides us with a new calibration of the extragalactic distance scale. It would be interesting to look for the Hubble constant derived directly
from these calibrating galaxies. Unfortunately, their radial velocities are dominated by the local velocity field and not by the cosmological velocity. Thus, they cannot be used directly, but can be used for the calibration of a long-range criterion, like the Tully-Fisher relation (Tully and Fisher, 1977).

The TF relation - relation between the 21-cm line width and the absolute magnitude - is thus far the best way to extend extragalactic distance measurements beyond the local universe where calibrators can be measured. The distance modulus derived from this relation can be written as:

\[ \mu = B_T^c - a \log V_M + b = B_T^c - a \log (W/2 \sin i) + b \quad (1) \]

where \( \mu \) is the distance modulus, \( B_T^c \) is the apparent total magnitude corrected for inclination and galactic extinction, \( V_M \) is the maximum velocity rotation, \( W \) is the 21-cm line width corrected for instrumental effect and non circular velocity, and \( a \) and \( b \) are two constants. This seems quite simple but some difficulties exist: All the corrections for inclination effects on both \( B_T^c \) and \( W \) depend on models which use the axis ratio \( R_{25} \) of the external isophotes and the morphological type code \( T \) of the considered galaxy. Further, it has been said that \( a \) and \( b \) also depend on \( T \) (Roberts, 1978; Rubin et al., 1985; Theureau et al., 1997) and it has been suggested that the linearity is not necessarily satisfied (Aaronson and Mould, 1983; Mould and Han, 1989). The use of the TF relation is plagued by these problems and the resulting distance scale may appear less convincing.

The second problem is related to a statistical bias (the so-called Malmquist bias). This bias can be understood as following. First of all, at large distances only the intrinsically brightest galaxies are seen because any sample is limited to a given apparent magnitude. In addition, the chance of finding galaxies over- or under-luminous (for their \( W \)) is higher in a large sample, i.e. at a large distance. These features are clearly illustrated by the Spahaue diagram (see Sandage, 1994), a diagram of absolute magnitude \( M \) versus radial velocity \( V \) (or distance).

In summary, if one wants to produce a sufficiently convincing value for the Hubble constant three difficulties have to be solved:

- there must be a secure zero-point calibration
- one has to correct for inclination effects and morphological type dependence.
- we have to overcome statistical biases like the Malmquist bias.

The first item (zero-point) is very important and will be discussed in section 2 in the light of new results obtained in studying the catalog of HIPPARCOS Cepheids. Then, the method of sosies-galaxies used to solve the second problem (corrections of secondary effects) is discussed in section 3. The third item (Malmquist bias) is considered in section 4. Finally, an application to sosie galaxies of M 31 and M 81 is made in section 5 and the results are presented in section 6.

2. Discussion of the distance scale calibration

From a general compilation of Cepheid measurements we derived distances for 17 galaxies using geometrical parallaxes of 10 galactic Cepheids provided by the HIPPARCOS satellite (Paturel et al., 1997). The result was obtained through a generalization of classical precepts.

Three important points should be emphasized:

- The equations were linear. Thus, they were used only on the range BVRI and only for relatively small extinction (because the ratio of total to differential extinction is assumed to be constant for a given effective wavelength).
- The distance modulus of a given galaxy was directly connected to the mean distance modulus \( \overline{\mu} \) of the HIPPARCOS galactic Cepheid sample. Any change in \( \overline{\mu} \) will affect the final result. The uncertainty on \( \overline{\mu} \) is large (\( \sigma(\overline{\mu}) \approx 0.2 \)) because it is based mainly on 10 calibrating Cepheids (those having the highest weights).
- Evidence is given that the Period-Luminosity relation (PL) is affected, at least in some galaxies, by a statistical bias (incompleteness bias, similar to the Malmquist bias).

The distance moduli found in this way were about 0.2 magnitude larger than those generally admitted. For instance, the distance modulus of Large Magellanic Cloud (LMC) was found to be \( \mu(\text{LMC}) = 18.7 \) (Feast and Catchpole, 1997; Paturel et al., 1997), while RR Lyrae stars give \( \mu(\text{LMC}) = 18.3 \) (Fernley et al., 1997), the SN1987 gives \( \mu(\text{LMC}) = 18.4 - 18.6 \) (Gould, 1995; Pana-gia et al., 1997). From independent studies on Cepheids, the distance moduli is found between 18.5 and 18.7 (Gieren et al., 1998; Gieren et al., 1993). Anyway, the distance modulus of LMC lies between 18.3 and 18.7. Our value is in favour of the large ones. In our first study (Paturel et al., 1997) the distance moduli for M 31 and M 81 were \( \mu(M31) = 24.8 \) and \( \mu(M81) = 28.1 \) without correction for the bias and \( \mu(M31) = 24.9 \) and \( \mu(M81) = 28.2 \), with a tentative correction. Our result was in favour of a long distance scale. Stricto Sensu, our results are compatible with the generally admitted distance moduli but the uncertainty on the zero-point is still large (0.2).

A new study has been undergone by one of us (PL) to revisit the HIPPARCOS PL calibration after the release of the whole HIPPARCOS catalogue. Some important conclusions are drawn:

- The value of \( \overline{\mu} \) obtained from HIPPARCOS parallaxes must be based on confirmed solitary Cepheids. We rejected binary stars in our original sample but many remaining ones may still be binaries. This point was already underlined by Szabados (1997) and confirmed by us. A part of this effect can be understood by the
nearness of confirmed solitary Cepheids which makes them less sensitive to the Lutz and Kelker bias (1973). This does not change the practical conclusion: It is better to base our zero-point on nearby solitary Cepheids.

Using all available solitary Cepheids from the HIPPARCOS mission we confirmed exactly the V-band PL relation of Gieren and Fouqué (1998) who give $\mu(LMC) = 18.4$. Then, adopting their I-band PL relation we applied the de-reddening method of Madore and Freedman (1991) and derived $\mu(M31) = 24.6$ and $\mu(M81) = 27.6$, without correcting for the bias (i.e. with all periods).

The incompleteness bias on the Cepheid PL relation has been independently confirmed using available HST observations and numerical simulations. It is generally small (less than 0.2 magnitude) because the dispersion of the PL relation is small. Nevertheless, correcting the bias (by constructing the growth curve $\mu = f(\log P)$) we derived $\mu(M31) = 24.7$ and $\mu(M81) = 27.7$.

In conclusion of this section, we will adopt $\mu(M31) = 24.6 \pm 0.2$ and $\mu(M81) = 27.6 \pm 0.2$ to derive the range of possible Hubble constant but we will keep in mind that our study with HIPPARCOS catalogue leads to distance moduli 0.1 mag larger after correction for incompleteness bias on the Cepheids Period-Luminosity relation.

Now we have to discuss a method to avoid uncertainties in the correction of secondary effects on the TF relation.

### 3. Overcoming secondary effects with sosies

We could make a model for correcting inclination effects and morphological type dependence. This necessarily leads to uncertainties because of the model dependency. The way we have chosen here is different. We will not try to correct for these perturbing effects but we will create a situation where the correcting terms disappear.

If one selects galaxies having very nearly the same morphological type, the same axis ratio and the same rotational velocity than a given calibrating galaxy (here, M 31 or M 81), they will have the same absolute magnitude as the calibrator. This is the direct consequence of Rel. 1. This approach (Paturel, 1981) is called the method of sosie galaxies (“sosies” is the French word for look-alike). Indeed, such galaxies will have the same appearance and the same physical properties. The distance modulus of a sosie galaxy is simply obtained by the relation:

$$\mu = \mu(\text{calib}) + B_T^c - B_T^c(\text{calib})$$  \hspace{1cm} (2)

where "calib" refers to the considered calibrator (M 31 or M 81) and $B_T^c$ is the apparent magnitude corrected for secondary effects. In this case, the corrections for inclination effects and morphological type dependence have no incidence of the final result because inclination and morphological type are the same. Nevertheless, a differential correction is required for the galactic extinction, but it is quite small because this is a differential secondary effect. This is still more valid because we restrict the selection to low extinction regions. Note that Sandage (1996) also made use of the concept of sosie galaxies by considering galaxies having the same morphological type and the same luminosity class.

### 4. Statistical bias

In our first application of the method of sosies (Paturel, 1981) we naively claimed that "this method is free from any Malmquist bias" because we thought that at a given rotational velocity only one single value of the absolute magnitude may exist. In fact, this is not correct. Sosies galaxies do have a dispersion of absolute magnitudes around a constant mean value. Making a magnitude limited sample selects the brightest galaxies of the distribution and then biases the sample.

The importance of the bias in connection with morphological luminosity classes was described as far back as 1975 (Sandage and Tammann, 1975; Teerikorpi, 1975a,b). Two diagrams help one to understand the bias. The Plateau diagram from which the method of the normalized distance is derived (Teerikorpi, 1984, Bottinelli et al., 1986) and the Spaenhauer diagram (Spaenhauer, 1978; Sandage, 1994). The connection between these diagrams has been recently reviewed by Teerikorpi (1997) who suggests the term Malmquist bias of the second kind for the distance dependent bias, to distinguish it from the classical Malmquist bias.

The Spaenhauer diagram shows how the absolute magnitude behaves as a function of the kinematical distance (i.e., distance estimated by the velocity). An illustration of this diagram is given in Fig. 8 for galaxies of a nominal absolute magnitude of $-21$. The equation of the envelope of the distribution (dotted curves in Fig. 8) can be calculated as $|M' - M_0| = c\log V + d$, where $c = 2\sigma/1.57$ and where $d$ is a function of the space density of considered galaxies (Paturel, 1998). $\sigma$ is the dispersion of the TF relation for the given rotation velocity.

The Plateau diagram shows how $\log H$ changes with the kinematical distance. For galaxies assumed to have the same absolute magnitude (like the sosies of a given calibrator) the Plateau diagram exhibits a plateau where $\log H$ is unbiased (see Figures 3 and 5). The method of the Normalized Distance consists in compressing or expanding the $x$–axis of the Plateau diagram according to the absolute magnitude so that the plateau becomes the same whatever the absolute magnitude of galaxies. This is achieved by multiplying the "distance" $V$ by $10^{0.2M}$. Because $M$ is not known a priori it can be replaced through the relation by $10^{0.2(M + a)}$, where $a$ is the slope of the Tully-Fisher relation. The thus corrected distance is called the norm-

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In the case of sosie galaxies we will use the absolute magnitude $M(\text{calib})$ of the calibrator to perform the normalization.
is given by Eq. (7). This curve is unique whatever the absolute magnitude (the equation does not depend on $M_o$).

In the Plateau diagram the limit can be deduced from:

$$\log H_{\text{lim}} = 0.2M_o + 5 - 0.2m_{\text{lim}} + \log V \quad (8)$$

In the Plateau diagram it is obvious that there is a completeness limit for each calibrator because $\log H_{\text{lim}}$ explicitly depends on $M_o$. When the normalization is applied on $x$-axis multiplying by $10^{0.2M_o}$, the completeness limit becomes unique for each $M_o$.

5. Application to M31 and M81 sosie galaxies

5.1. The sample

In the present paper we use only the calibrators M31 and M81 because they are the brightest ones. The main characteristics of these galaxies are given in Table 1. All observed astrophysical parameters are taken from the LEDA database which is freely accessible. Distance moduli are taken according to the discussion of section 2 and the absolute magnitudes are derived from them using the corrected apparent magnitudes. Note that the correction for galactic extinction on magnitudes are taken following the RC2 system (de Vaucouleurs et al., 1976). The essential difference with the Burstein-Heiles model occurs near the galactic poles (see Paturel et al., 1997) where the extinction is assumed to be 0.2 magnitudes. However, this has no influence on the present results because the constant term is cancelled in our differential method.

Using the LEDA database we selected sosie galaxies, i.e. galaxies having nearly the same morphological type code ($T$), the same log of axis ratio ($\log R_{25}$) and the same rotational velocity ($\log V_M$), as M31 or M81. Further, we selected only galaxies with accurate apparent magnitude ($\sigma(B_T) \leq 0.4$) and rotational velocity ($\sigma(\log V_M) \leq 0.08$) and no discrepancies in observed radial velocity. The tolerances are chosen to equal a typical error in each parameter. They are $\pm 1.5$ for the morphological type code, $\pm 0.12$ for $\log R_{25}$ and $\pm 0.08$ for $\log V_M$.

Using such criteria we obtained a sample of 43 sosies of M31 and 119 sosies of M81. For each galaxy the following

$$\text{telnet: telnets leda.univ-lyon1.fr, login: leda or world-wide-web: http://www-obs.univ-lyon1.fr/leda}$$

Table 1. Parameters of Calibrating Galaxies

| parameter     | M 31       | M 81       |
|---------------|------------|------------|
| $\mu$         | $24.6 \pm 0.2$ | $27.6 \pm 0.2$ |
| $M_B$         | $-21.49$   | $-20.62$   |
| $T_{\text{code}}$ | $3.0 \pm 0.3$ | $2.5 \pm 0.6$ |
| $\log R_{25}$ | $0.48 \pm 0.05$ | $0.31 \pm 0.07$ |
| $B_T$         | $3.11 \pm 0.4$ | $6.98 \pm 0.32$ |
| $\log V_M$   | $2.397 \pm 0.010$ | $2.338 \pm 0.022$ |

Fig. 1. Spaenhauer diagram: for a sample of galaxies, limited to an apparent magnitude and having on the mean the same absolute magnitude only galaxies above the completeness limit are visible (dashed curve). The dispersion around the mean increases with the size of the sample (i.e. with the distance) but reaches a physical limit as shown by the envelopes (dotted curves). The actual mean apparent absolute magnitude will follow the solid line. The vertical line shows where the bias begins.

The completeness limit curve (dashed curve in our diagrams) will show where the sample is cut. No galaxies will appear below this limit for the considered absolute magnitude. In the Spaenhauer diagram the completeness limit

$$\Delta M = M' - M_o = \sigma \sqrt{\frac{2}{\pi}} \frac{e^{-A^2}}{1 + erf(A)} \quad (3)$$

with

$$A = \frac{M_{\text{lim}} - M_o}{\sigma \sqrt{2}} \quad (4)$$

and

$$erf(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt \quad (5)$$

and

$$M_{\text{lim}} = m_{\text{lim}} - 25 - 5 \log V/H_o \quad (6)$$

The bias curve in the Plateau diagram is simply:

$$\Delta \log H = \log H' - \log H_o = -0.2 \Delta M \quad (7)$$
parameters are known (they all conform to the description given by Paturel et al., 1997):

- Column 1: PGC name according to Paturel et al. (1989a,b)
- Column 2: Right ascension and Declination for 2000 in (h, mn, s) and (deg, arcmin, arcsec) respectively.
- Column 3: Corrected total $B_T$ magnitude in the RC3 system (de Vaucouleurs et al., 1991) - except for the galactic extinction.
- Column 4: Radial velocity corrected for the infall of the Local Group onto the Virgo cluster. The infall velocity is 170 km.s$^{-1}$ according to Sandage and Tammann (1990), the position of the Virgo cluster is $SGL = 104$ deg and $SGBD = -2$ deg, in supergalactic coordinates. This velocity is used as a relative kinematical distance.

As we saw in previous section, in order to use the Normalized Distance method it is compulsory to have a sharp apparent limiting magnitude in our sample. This magnitude limit and the resulting useful sample can be derived by constructing the curve $\log N$ vs. the apparent magnitude $B_T$. ($N$ is the cumulative number of galaxies with $B_T < B_{lim}$). The result must be a straight line. The magnitude at which the curve bends down gives the limiting magnitude $B_{lim}$. The slope should be $0.6 = 3/5$ if the distribution of galaxies is homogeneous ($N \propto r^3$). In practice, this value is rarely reached. The slope is always lower. In the local universe it has been shown that the slope is close to $0.4 = 2/5$ (Paturel et al., 1994). This is also consistent with a recent derivation of the radial space density by a method using the Tully-Fisher distance moduli (Teerikorpi et al., 1998).

For our sample the completeness curve $\log N$ vs $B_T$ is built (Fig. 1) by combining sosies of both calibrators M31 and M81 (the apparent limiting magnitude is an observational limit which does not depend on the absolute magnitude of considered objects). The completeness is fulfilled up to an apparent magnitude of $B_{lim} \approx 12.5$. The slope is in agreement with our previous result (0.4).

Thus, the diagrams will be made using only galaxies brighter than $B_T = 12.5$. The corresponding sample is given in the Annex.

### 5.2. Construction of the Plateau diagram

The Hubble constant is calculated from the relation:

$$\log H' = \log V_{Vir} - 0.2 \mu(\text{calib}) + B_T - B_T(\text{calib}) - 25$$

for each galaxy for which $V_{Vir} \geq 500$ km.s$^{-1}$ (with this radial velocity limit we avoid the effect of random peculiar velocities). Figures 3 and 4 show the Plateau diagrams, $\log H'$ vs. $V_{Vir}$, for M31 and M81 respectively. The bias curve (Eq. 7) is calculated using $B_{lim} = 12.5$ (previous section) and $\sigma = 0.7$ mag (Fouqué et al., 1990). The expected increase of $\log H'$ is clearly visible. It reveals the presence of a Malmquist bias. The velocity at which the bias becomes significant (i.e. $\Delta M \approx 0.05$) is 2000 km.s$^{-1}$ for M 31 and 1400 km.s$^{-1}$ for M 81.

For sosie galaxies of a given calibrator, the Plateau diagram has the same meaning than the Spaenhauer diagram. The deviation of $\log H'$ simply reflects the corresponding deviation of $M'$ in the Spaenhauer diagram.
5.3. Mean Hubble constant derived from the geometrical zero-point

The final sample of unbiased galaxies is given in Table 2. It is rather small as expected from the size of the sosies sample and from the restriction $V_{\text{vir}} \geq 500 \, \text{km.s}^{-1}$.

| M 31 sosies | $B_{\text{v}}$ | $V_{\text{vir}}$ | $\log H_o$ |
|------------|---------------|-----------------|-----------|
| PGC14638   | 9.61          | 995             | 1.778     |
| PGC39724   | 10.40         | 1053            | 1.644     |
| PGC51233   | 10.57         | 1559            | 1.781     |
| mean       |               |                 | 1.78 ± 0.04|

| M 81 sosies | $B_{\text{v}}$ | $V_{\text{vir}}$ | $\log H_o$ |
|------------|---------------|-----------------|-----------|
| PGC00218   | 10.87         | 1147            | 1.762     |
| PGC10208   | 10.41         | 960             | 1.776     |
| PGC33550   | 8.98          | 771             | 1.967     |
| PGC35164   | 10.38         | 935             | 1.771     |
| PGC37306   | 9.96          | 1258            | 1.984     |
| PGC43798   | 11.52         | 1051            | 1.594     |
| mean       |               |                 | 1.78 ± 0.04|

Table 2. Sample of unbiased galaxies

From the mean $\log H_o = 1.78 ± 0.04$ we derive the Hubble constant $H_o = 60 ± 5(\text{internal}) \, \text{km.s}^{-1}.\text{Mpc}^{-1}$. If we are using the extreme values for $\mu_{\text{calib}}$ we find that the Hubble constant lies between 47 and 65 km.s$^{-1}$.Mpc$^{-1}$.

6. Conclusion

A reasonable value of the unbiased Hubble constant would be:

$$H_o = 60 ± 10(\text{external}) \, \text{km.s}^{-1}.\text{Mpc}^{-1}$$

(10)

Nevertheless, we believe that the correct value is more probably near the lower limit because we have demonstrated that the PL relation of Cepheids also suffers from a statistical bias.

It is clear, that the bias appears already at a short distance, even when a luminous galaxy is used as calibrator. Hence, it is difficult to obtain a secure Hubble constant from low luminosity galaxies. Indeed, then restricting the sample to the unbiased plateau requires a cut at a very low radial velocity, just where random velocities start to dominate. This justifies that we used first M 31 and M 81 as calibrators. However, one should ask whether these galaxies have an absolute magnitude representative of their rotation velocity. The positions of M 31 and M 81 in a TF diagram are quite normal (see for instance Fouqué et al., 1990), which supports that they are good calibrators.

The positive sides of the sosies method make it necessary to enlarge the sample in the future. This can be achieved only by using deeper samples which require more HI measurements. Besides, weaker sosies criteria which require that galaxies have the same morphological type and the same axis ratio, but not necessarily the same 21-cm
line width $W$ as a calibrator will greatly improve the accuracy of the TF relation because inclination and morphological type effects will be cancelled.

Another way to improve the result may come from infrared photometry. Indeed, even with the method of sosie galaxies it is necessary to correct for galactic extinction. Obviously, only the difference between the extinctions in front of the sosies galaxy and the calibrator enter the final result. Nevertheless, it is still a part of the uncertainty.

In view of this promising aspects, we are engaged in a program aiming at collecting deeper samples of sosie galaxies especially in the infrared domain.

References

Aaronson M., Mould J., 1983, ApJ 265, 1
Bottinelli, L. Gouguenheim, L. Paturel, G. Teerikorpi P., 1986, AA 156, 157
de Vaucouleurs G., de Vaucouleurs A., Corwin H.G., Buta R.J., Paturel G., Fouqué P., 1991, Third Reference Catalogue of Bright Galaxies, Springer-Verlag (RC3)
de Vaucouleurs G., de Vaucouleurs A., Corwin H.G., 1976, Second Reference Catalogue of Bright Galaxies, University of Texas Press, Austin (RC2)
Mould J. and Han M., 1989, ApJ 347, 112
Feast M.W., Catchpole R.M., 1997, MN 286, L1
Fernley J., Barnes T.G., Skillen I., Hawley S.L., Hanley C., Evans D.W., Solano E., Garrido R., 1997, Proceedings of the ESA Symposium ‘Hipparcos-Venice 97’, Venice, Italy, ESA SP-402, p635
Fouqué P., Bottinelli, L. Gouguenheim, L. Paturel, G., 1990, ApJ 349, 1
Gieren W., Fouqué P., 1993, AJ 106, 734
Gieren W., Fouqué P., Gómez M., 1998, ApJ 496, 17
Gould A., 1995, ApJ 452, 189
Lutz T.E., Kelker D.H., 1973, PASP 85, 573
Madore B.F., Freedman W.L., 1991, PASP 103, 933
Paturel G., 1981, ApJ 282, 382
Paturel G., Bottinelli L., Di Nella L., Fouqué P., Gouguenheim L., Teerikorpi P., 1994, AA 289, 711
Paturel G., Andernach H., Bottinelli L., Di Nella H., Durand N., Garnier R., Gouguenheim L., Lanoix P., Marthinet M.C., Petit C., Rousseau J., Theureau G., Vauglin I., 1997, AAS 124, 109
Paturel G., Fouqué, P., Bottinelli, L., Gouguenheim, L., 1989a, Monographies de la base de données extragalactiques No.1 (volumes I, II and III)(ISBN 2.908288.00.1)
Paturel G., Fouqué, P., Bottinelli, L., Gouguenheim, L., 1989b, AA 80, 299
Paturel, G., Lanoix P., Garnier R., Rousseau J., Bottinelli L., Gouguenheim L., Theureau G., Turon C., 1997, Proceedings of the ESA Symposium ‘Hipparcos-Venice 97’, Venice, Italy, ESA SP-402, p629.
Paturel G., 1998, AA (in preparation)
Panagia N., Gilmozzi R., Kirshner R., 1997, in: ‘SN1987A: Ten years after’ eds. M. Phillips, N. Suntzeff, ASP Conf. Series (in press)
Roberts M.S., 1978, AJ 83, 1026
Rubin V.C., Burstein D., Ford Jr. W.K., Thonnard N., 1985, ApJ 289, 81
Sandage A., 1994, ApJ 430, 1
Sandage A., 1996, AJ 111, 18
Sandage A., Tammann G., 1990, ApJ 365, 1
Spaenhauer A.M., 1978, AA 65, 313
Szabados L., 1997, Proceedings of the ESA Symposium ‘Hipparcos-Venice 97’, Venice, Italy, ESA SP-402, p657
Teerikorpi P., 1975a, Observatory 95, 105
Teerikorpi P., 1975b, AA 45, 117
Teerikorpi P., 1984, AA 141, 407
Teerikorpi P., 1997, Annu. Rev. Astron. Astrophys. 35, 101
Teerikorpi P., Hanski M., Theureau G., Baryshev Yu., Paturel G., Bottinelli L., Gouguenheim L., 1998, AA 334, 395
Theureau G., Hanski M., Teerikorpi P., Bottinelli L., Ekholm T., Gouguenheim L., Paturel G., 1997, AA 319, 435
Tully,R.B., Fisher,J.R., 1977, AA 54, 661

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Annex: Samples of M 31 and M 81 sosie galaxies brighter than BTc=12.5.

| PGC name   | RA.(2000) | DEC.    | BTc  | V(Vir) |
|------------|-----------|---------|------|--------|
| M 31       | 004244.4+411608 | 3.11    | -116 |        |
| PGC05268   | 012519.7+340128 | 12.41   | 4902 |        |
| PGC05344   | 012621.6+344214 | 12.22   | 5338 |        |
| PGC10048   | 023912.2+105050 | 12.31   | 3547 |        |
| PGC14638   | 041205.5-325228 | 9.61    | 995  |        |
| PGC26157   | 091619.6-233804 | 11.45   | 2368 |        |
| PGC36964   | 114950.1-384705 | 11.71   | 2644 |        |
| PGC39724   | 121950.9+293654 | 10.40   | 1053 |        |
| PGC51233   | 142020.5+035559 | 10.57   | 1559 |        |
| PGC54001   | 150735.4+193457 | 12.11   | 4891 |        |
| PGC55256   | 153007.8-383857 | 12.15   | 4522 |        |
| PGC55740   | 153958.1+580457 | 11.70   | 3264 |        |
| PGC62951   | 191443.8-621618 | 11.46   | 4148 |        |
| PGC63214   | 192649.8-545704 | 11.63   | 2989 |        |
| PGC63464   | 193842.8-294832 | 12.31   | 6011 |        |

| PGC name   | RA.(2000) | DEC.    | BTc  | V(Vir) |
|------------|-----------|---------|------|--------|
| M 81       | 095533.5+690400 | 6.98    | 201  |        |
| PGC00218   | 000315.1+160845 | 10.87   | 1147 |        |
| PGC03260   | 005507.9+313229 | 12.22   | 5606 |        |
| PGC04777   | 011945.5+032437 | 11.87   | 2381 |        |
| PGC07525   | 015920.3+190022 | 10.28   | 2524 |        |
| PGC10208   | 024144.7+002631 | 10.41   | 960  |        |
| PGC13059   | 033108.4-333744 | 10.54   | 1699 |        |
| PGC13108   | 033203.1-204904 | 11.53   | 1379 |        |
| PGC13179   | 033336.6-360817 | 9.73    | 1454 |        |
| PGC13584   | 034157.2-044221 | 12.07   | 4045 |        |
| PGC18355   | 060340.2-693541 | 12.09   | 3678 |        |
| PGC23086   | 081414.4+212125 | 12.43   | 3401 |        |
| PGC23362   | 081948.2+220138 | 12.46   | 3622 |        |
| PGC24427   | 084135.0+201858 | 11.76   | 5555 |        |
| PGC24464   | 084240.1+141710 | 12.02   | 2056 |        |
| PGC24558   | 084430.1-202101 | 11.82   | 3291 |        |
| PGC25097   | 085607.9-032139 | 11.94   | 1924 |        |
| PGC28376   | 095115.8-324518 | 11.31   | 2587 |        |
| PGC29591   | 101009.9-122602 | 11.71   | 3545 |        |
| PGC29993   | 101619.3-333353 | 11.65   | 2725 |        |
| PGC31335   | 103508.5+434132 | 10.60   | 2663 |        |
| PGC31533   | 103715.6+431742 | 11.04   | 2560 |        |
| PGC33550   | 110548.9+000215 | 8.98    | 771  |        |
| PGC35164   | 112607.7+433506 | 10.38   | 935  |        |
| PGC37306   | 115349.5+521939 | 9.96    | 1258 |        |
| PGC39212   | 121533.7-353746 | 11.69   | 2773 |        |
| PGC39656   | 121922.0+006001 | 12.17   | 1864 |        |
| PGC43798   | 125329.1+021011 | 11.52   | 1051 |        |
| PGC45170   | 130414.6-102021 | 11.05   | 3064 |        |
| PGC46304   | 131743.4-320605 | 11.59   | 2174 |        |
| PGC49359   | 135328.1+375462 | 12.36   | 3812 |        |
| PGC49653   | 135616.8+471417 | 11.75   | 2006 |        |
| PGC50031   | 140250.5+491025 | 11.59   | 2240 |        |
| PGC51932   | 143205.2+576524 | 11.13   | 2179 |        |
| PGC54364   | 151345.7-141615 | 11.42   | 1963 |        |
| PGC62178   | 183833.7+252238 | 11.48   | 3620 |        |
| PGC62528   | 185255.5-591520 | 11.87   | 3451 |        |
| PGC64601   | 202334.0+062638 | 11.81   | 4955 |        |
| PGC64884   | 203138.5-305001 | 11.75   | 2761 |        |
| PGC67839   | 220102.0-131610 | 12.26   | 2700 |        |

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