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DISTANCE DETERMINATIONS TO NEARBY GALAXIES

by

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Praefatio Latine

propositi doctori philosophiae

Hoc opus fundamentum habet in investigatio machinationum rerumque mundi magnitudinum. Intervalla alia circorum lacteorum necessari sunt rerum earum et structurarum globorum circorum lacteorum comprendum. Metivimus intervalla intus iactus de quinquaginta duo decies centena milia annum lucis; ad sedecim nanum circum lacteum ovatum et duo magnum circum lacteum intortum. Intervalla oblati sunt in quattuor charta comitata. Diversi modi de metiri intervallae explicati sunt et unum confirmatus est.

Felix qui potuit rerum cognoscere causas!

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Abstract

Determining the distances to galaxies is an essential part of the process of deciphering the structures they form and of the phenomena, which occur in them. Local galaxy space is a fairly typical place in the cosmos. Two giant spiral galaxies dominate in the Local Group of galaxies. Giant elliptical galaxies are found in several neighbouring groups and hundreds of other galaxies covering the entire range of Hubble classification are to be seen in the closest dozen or so galaxy groups. Even the large Virgo cluster of thousands of galaxies is only about 20 Mpc from us. There is a myriad of phenomena to be studied closeby — many of which shed much light in the workings and structure of the Universe and help to explain some of the phenomena we see in more distant galaxies.

In this thesis, a range of techniques is used to measure distances for several types of galaxies out to about 16 Mpc. The techniques used are via (1) Cepheid variable stars, (2) the use of the planetary nebula luminosity function (PNLF) and (3) the method of surface brightness fluctuations (SBF). The fundamentals of these methods are presented in the introductory part of the thesis.

Cepheids have been used to measure the distance to IC 342 — a large spiral galaxy in the IC 342 / Maffei group. The distance to this galaxy is poorly known although it is quite close by, because it is quite heavily shrouded by dust in the Milky Way. We used the planetary nebula luminosity function method to measure the distance to NGC 253 — a large spiral galaxy in the Sculptor group. The distance of the galaxy has been difficult to measure because it is very dusty. The planetary nebula luminosity function method is shown in this thesis to be very appropriate because it is much less sensitive to dust than other methods. Finally, the surface brightness fluctuation method was used to derive distances to sixteen dwarf elliptical galaxies out to about 16 Mpc. Local space contains many such dwarf galaxies, and we show that the surface brightness fluctuation method is a very precise and practical means of obtaining distances to them. Many of the dwarf galaxy distances have been measured for the first time in this thesis.

Distances to six dwarf ellipticals using the surface brightness fluctuation method, spanning a range of 3.1 to 10.5 Mpc, are given in the Paper I, along with the first empirical calibration of surface brightness fluctuations for this galaxy type. Paper II employs the planetary nebula luminosity function to derive a distance of 3.6 ± 0.2 Mpc to NGC 253. Paper III employs the surface brightness fluctuation method on ten additional dwarf ellipticals, spanning a distance range of 3.3 to 16.0 Mpc. A Cepheid distance of 3.8 ± 0.4 Mpc to IC 342 is presented in Paper IV.

A comparative study of distances in the literature to all known or putative Extended Local Group galaxies is also presented.

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CHAPTER 1

Introduction

The scientific justification for measuring distances to galaxies is not only in the distances themselves. On the simplest level distances allow us to construct a three-dimensional picture of the structures galaxies form in space while many of the phenomena studied in galaxies require the distance to be known. Distances in astronomy are built up upon a chain of key object types, and presently allow us to measure distances from a scale of few parsecs to scales of gigaparsecs.

Distances are measured in a variety of ways, most of them indirect. Within the solar system distances have been measured directly using radar. Out to about a hundred parsecs, stellar distances are measured via the parallax effect. Extragalactic distances to several tens of megaparsecs are measured with many different methods, which mostly concentrate in finding objects whose true luminosity can be inferred in some manner.

Currently the most popular and reliable distance measuring methods utilizes the well known correlation between the absolute magnitude and variability period of Cepheids (e.g. Madore & Freedman 1998). The method has been extensively employed using the Hubble Space Telescope (HST) to establish distances to over forty galaxies out to about 23 Mpc (Ferrarese et al. 2000). A presently underemployed method establishes distance by measuring the brightness of planetary nebulae in a galaxy, and comparing the luminosity function to the well studied luminosity function of planetary nebulae in the Andromeda Galaxy (Jacoby et al. 1992). This method ought to be more widely utilized, particularly as we show in this thesis that it is much less sensitive to dust obscuration than most other methods. Another new, powerful method measures distances to elliptical galaxies from the variance of the amplitude of luminosity fluctuations on images (e.g. Jacoby et al. 1992).

In this thesis all these three methods have been used to measure distances. We use the surface brightness fluctuation method on several dwarf ellipticals out to 16 Mpc to chart the structure of local galaxy groups. We use Cepheids on a massive spiral galaxy in IC 342 / Maffei group and planetary nebula luminosity function on a spiral galaxy in Sculptor group. These groups are the closest neighbours to our own Local Group.

Because of relatively high radial velocities for their distances galaxies in IC 342 / Maffei group and Sculptor group have been theorised of having a shared dynamical history with the Local Group (Sandage 1987, McCall 1989, Zheng et al. 1991, Byrd et al. 1994, Peebles 1994). To check upon this assumption distances to some of the important galaxies in these groups have been measured.

From the IC 342 / Maffei group one of the most prominent members, IC 342 itself, was chosen for this purpose. When the study began, there was no Cepheid distance to the galaxy and distance estimates ranged from 1.5 Mpc (Ables 1971) to 7.9 Mpc (Sandage 1974) with a recent measurement by McCall (1989) establishing a very high value of extinction towards the galaxy and suggesting a dynamical link to the Milky Way. From the Sculptor group the central galaxy of the more distant concentration, NGC 253, was chosen to be studied. This galaxy is an active starburst galaxy with a high dust content. The planetary nebula luminosity function method is quite insensitive to the dust and was employed to consolidate the distance that used to range from 2.1 Mpc (Issa 1982) to 3.9 Mpc (Karachentsev et al. 2003).

The dwarf galaxies studied were selected from recent discoveries of a large number of low surface brightness galaxies by Côté et al. (1997), Karachentseva and Karachentsev (1998), and Jerjen et al. (2000a) for the purpose of mapping the Extended Local Group contents and surroundings with the surface brightness fluctuation method that was recently adopted for dwarf ellipticals (Jerjen et al. 1998). The new method is the first comprehensive means of measuring proper distances to these objects.

A comparison of known distance estimates to all Extended Local Group galaxies has been included in this thesis partly to establish the use and comparability of various distance measuring methods and partly to build a comprehensive database of the Extended Local Group for future use in dynamical studies.

CHAPTER 2
Nearby galaxy space

2.1 The Extended Local Group and galaxies therein

The Milky Way is a giant spiral galaxy containing at least a hundred billion stars with recent total mass estimates ranging from $1.3^{+2.9}_{-1.0} \times 10^{12}$ $M_\odot$ to $2.5^{+0.5}_{-1.0} \times 10^{12}$ $M_\odot$ (Bellazzini 2004 and Wong et al. 2004 respectively). Together with another similar giant spiral galaxy, the Andromeda Galaxy (M31), it forms a dynamical pair (Kahn & Woltjer 1959). They may collide and merge within a Hubble time (Nagamine & Loeb 2003). Both galaxies host a multitude of companions – dwarf galaxies with masses barely a per mille of those of their respective host galaxies and a few small galaxies that have masses of several per cent of their hosts. Altogether there are some forty members of this ensemble, called the Local Group of galaxies, all within a radius of one megaparsec from the Local Group barycentre. It is more than likely that there are a few as yet undiscovered members of the Local Group.

Most galaxies are dynamically bound into groups or clusters of tens or even hundreds of galaxies. The Local Group is surrounded by other groups, as shown in Fig. 2.1. Groups and clusters of galaxies further form superclusters. The Local Group is part of the Local Supercluster, a conglomeration of some $\approx 10^{16}$ $M_\odot$ extending ≈50 Mpc in size (Tully 2004). Beyond this scale the Local Supercluster is part of the Virgo–Hydra–Centaurus Supercluster (Tully 1988).

The term “Extended Local Group” is generally used quite loosely. Some people extend the dynamical boundary of the Local Group to include several field galaxies, which may or may not be (or have been) in dynamical interaction with the Local Group proper (e.g. de Vaucouleurs et al. 1977, Hartwick 2000). Even the nearby IC 342 / Maffei group of galaxies and the closer half of the Sculptor group have been speculated to share some common dynamical history with the Local Group galaxies (e.g. Byrd et al. 1994, Valtonen et al. 1994). Even though this seems quite unlikely with current knowledge on the distances of these groups (see Papers II and IV of this thesis), the Extended Local Group is used in this thesis as a term that describes the Local Group, the IC 342 / Maffei group and several field galaxies as well as the Sculptor group of galaxies as it is nowadays defined (see Appendix A).

The Local Group of galaxies forms the core of the Extended Local Group consisting of the Milky Way – Andromeda Galaxy pair and some forty smaller galaxies. A large frac-

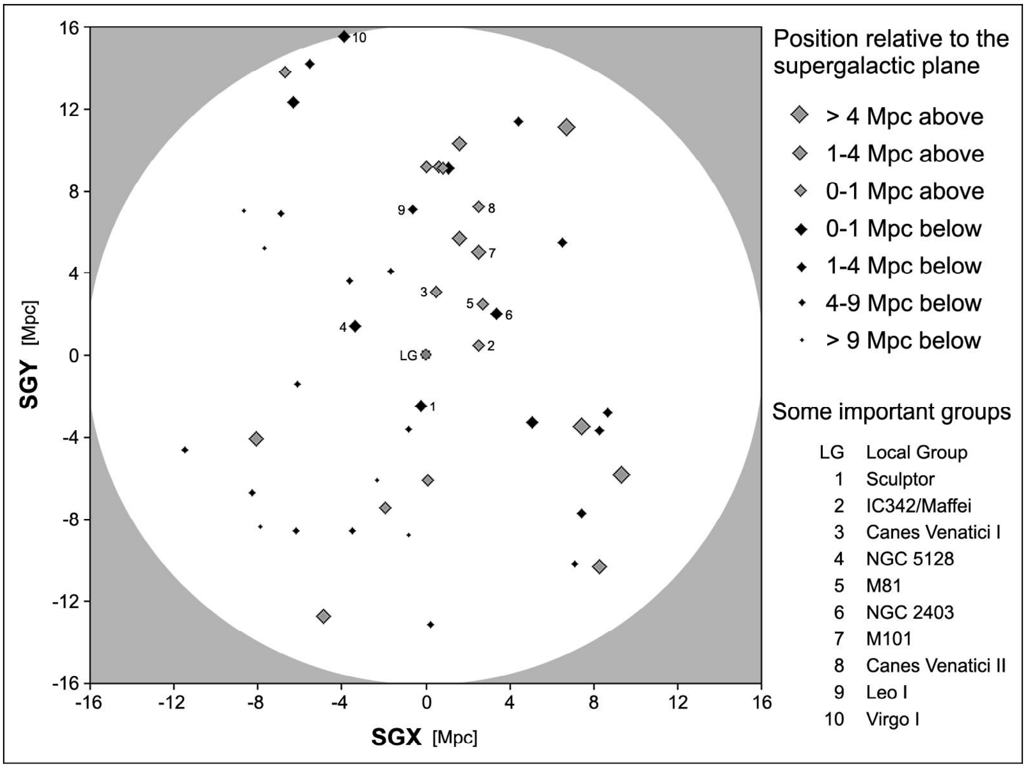

Figure 2.1: *The Local Group of galaxies and neighbouring groups within a radius of 16 Mpc. The group position is projected onto the supergalactic plane and its altitude from the plane is indicated by the size and shading of the symbol. All groups in the range of 5 Mpc are named; numbers 1–6;as well as some others further away. Position data has been adopted from Tully (1988).*

tion of these galaxies are dwarf spheroidals with old stellar populations (da Costa 1998). The most notable spiral galaxy, besides the two giants spirals, is M33, which is in orbit around the Andromeda Galaxy. Two conspicuous irregular galaxies, the Large and Small Magellanic Clouds, are close companions of the Milky Way. Their proximity and the intermediate Magellanic Stream provide an ideal test case for dynamical studies of the formation of the stream, composition of the Magellanic clouds and effects they may have had on their parent galaxy (e.g. Yoshizawa & Noguchi 2003). More directly connected to this thesis, the Large Magellanic Cloud is an often used reference point for the extragalactic distance scale.

The IC 342 / Maffei group lies at a distance of a few megaparsecs from the centre-of-mass of the Local Group (see Appendix A). The group is very difficult to observe from the Earth as it is behind the zone-of-avoidance[1]. There are at least three large galaxies in the group: Maffei 1 is a large elliptical galaxy while its companion, Maffei 2, and IC 342 are large spiral galaxies (de Vaucouleurs et al. 1991). Several other dwarf and giant galaxies belong to the group and it is quite possible more will be found when this difficult area of the sky is studied in more detail.

What was once considered the Sculptor group has been found to be a long stream of galaxies with several concentrations (Jerjen et al. 1998). The most distant parts of the original group have been assigned their own group status around the giant spiral galaxy NGC 45. The closer parts are probably concentrated around NGC 253 and NGC 300; both spiral galaxies. Both concentrations host a large number of dwarf galaxies orbiting their respective parents (Karachentsev et al. 2003).

All currently known and suspected Extended Local Group galaxies, with some of their characteristics, are listed in Appendix A and a comparison of distances from literature is made in Appendix B. Furthermore, a World Wide Web database of the Extended Local Group galaxies is introduced in Appendix C.

2.2 Dynamical interactions

In both Newtonian and Einsteinian theory the gravity of a massive body affects all other bodies in the Universe. However, within the context of an expanding Universe the distance at which gravitational effects are manifest is limited. Groups and clusters of galaxies are bound systems because gravity has played a greater rôle than the expansion over the age of the Universe, some fourteen billion years.

Dynamical interactions between galaxies within groups are of considerable interest. Not only can they reveal to us something about the properties of galaxies but they also provide information on the history of the group and galaxies therein. The velocities of galaxies in groups can be used to calculate the group mass or the mass of the central body (Binney & Tremaine 1994). Velocity dispersion gives an indication of the group age (Proctor et al. 2004).

A major effort is underway in astronomy at present to study galaxy group dynamics with computer simulations. Such simulations have been run since 1970’s when computers began to be powerful enough for such work. Simulations of a few galaxies or larger galaxy groups have provided much insight into many particular problems found from

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[1] The position of the Earth in the Milky Way affects all extragalactic astronomy in many ways. Depending on the direction of another galaxy seen from the Earth there is a varying amount of extinction due to dust and gas in the Milky Way. In extreme cases the extinction affects light from extragalactic sources by more than ten magnitudes; e.g. extinction in B-band towards Maffei 2, a nearby galaxy, is 10.013 magnitudes (Schlegel et al. 1998). The most extincted area on the sky is the belt formed by a high concentration of stars, gas and dust in the galactic disk. Because observations through it are quite difficult and often biased, this belt is called the zone-of-avoidance.

observations or suggested by theory. They have demonstrated how some of the black holes in merging galaxies may be ejected by system instabilities (e.g. Mikkola & Valtonen 1990), or how galaxies merge or are ejected in few-body interactions (e.g. Wirén et al. 1996). Simulations can be used to study group formation and cosmological parameters (e.g. Valtonen et al. 1993). Our particular interest lies naturally with the Extended Local Group dynamics. The distances obtained in this thesis are part of an effort to constrain scenarios for the dynamical history of the group (e.g. Valtonen et al. 1993).

2.3 Extended Local Group dynamics

Dynamical interactions in the Local Group are especially interesting, because we can measure relatively accurate distances between the Local Group galaxies, we have accurate radial velocities to these galaxies, and in the near future we begin to have measurements of proper motions for galaxies within a megaparsec using the Global Astrometric Interferometer for Astrophysics (GAIA) satellite (Peebles et al. 2001, Tammann & Reindl 2002).

Early simulations on the Local Group dynamics projected galaxies onto a plane, which was a fair approximation as the galaxies are mostly concentrated on the Supergalactic Plane (de Vaucouleurs et al. 1977). Nowadays simulations are usually run in full three-dimensional space and all known Extended Local Group galaxies can be included without the need to resort to supercomputers (e.g. Klypin et al. 1999).

The work done in the 1980's and early 1990's traced the Local Group history, movements of its galaxies, scale and timing of close interaction between galaxies, possible common history with neighbouring groups and the age of the Universe through Local Group Timing (e.g. Peebles et al. 1989, Byrd et al. 1994, Valtonen et al. 1993, and Peebles 1994).

With all this knowledge and a fine-tuned set of dynamical simulations we are able to answer even cosmological questions; such as the age of the Universe – independent of the Hubble constant. The distances obtained within this thesis work have enabled us to set constraints on the galaxies worth including in simulations. We have found that the Sculptor group concentration around NGC 253 seems too distant and too well adjusted to the Hubble flow to be included. However, the proximity of the other concentration around NGC 300 should be studied with more care. The surface brightness fluctuation method may be used for dwarf companions of NGC 300 as shown in papers I and III of this thesis. Our own and other recent distance measurements to the IC 342 / Maffei group suggest that it has no present or past influence on Local Group dynamics. With these assumptions new dynamical studies may return to the original idea of a Milky Way – Andromeda Galaxy dynamical pair forming the core of the Local Group dynamics (Kahn & Woltjer 1959); with small and dwarf galaxies adding a more complex component, enabling us to study the Local Group history through observed starburst phases of galaxies in relation to simulated close interaction with other galaxies (Rekola 1997). Our distance measurements strongly indicate that Local Group timing arguments for the age of the universe and mass of the Local Group are not seriously in error because of potential effects of Extended Local Group members.

CHAPTER 3
Distance measurements

Dozens of methods have been devised to measure distances in astronomy. Most of these methods are applicable only to certain kinds of objects and only to a distance maximum, which depends on the properties of the object used by the method. With a few exceptions all distance measuring methods are based on “standard candles” for which theory or observations have yielded an absolute magnitude. Once an apparent magnitude is observed the distance modulus ($m-M$) can be calculated, and converted to a distance in parsecs using equation

$$m-M=5\log\left(\frac{r}{10\ \mathrm{pc}}\right)+A(r) \tag{3.1}$$

where m is the apparent and M the absolute magnitude of the object, r the distance in parsecs, and A the interstellar or galactic extinction. This chapter discusses in detail the three distance measuring methods applied in this thesis work – Cepheid variable stars, planetary nebula luminosity function and surface brightness fluctuations – and briefly summarizes others.

3.1 Cepheid variable stars

Some of the most powerful distance measuring methods utilize variability in the standard candle, most commonly a regular variation of brightness. The most commonly used distance measuring method of this type takes advantage of regular and well understood variability of stars known as Cepheids. The name is derived from δ Cephei that was the first star of this type identified as a variable by John Goodricke in 1784. The objects were later famously utilized by Leavitt (1908) to establish the foundations of the extragalactic distance scale.

Classical Population I Cepheids are yellow supergiant stars and have absolute visual magnitudes of $-2 > M_V > -7$ mag. They undergo regular radial pulsations with periods mainly in the range of 2 – 100 days, with some detections of longer periods up to 250 days (Madore & Freedman 1998). As illustrated in Fig. 3.1 the characteristic Cepheid light curves rise rapidly to maximum light and deline slower to minimum light. Cepheids are brightest at redder wavelengths, but their variability amplitude, up to a couple of magnitudes, is greatest at bluer wavelengths. For an extensive review, see Madore & Freedman (1998).

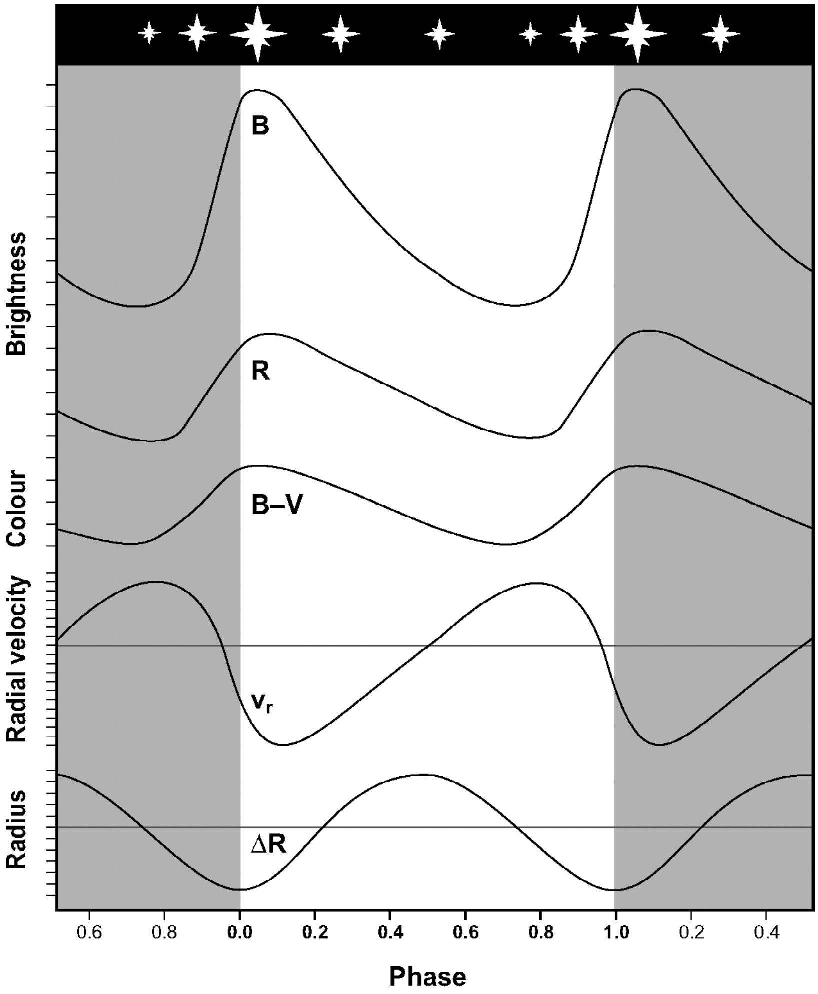

Figure 3.1: *Cepheid variable star properties. Depicted are B- and R-band magnitudes, B–V colour, radial velocity and radius of a typical Cepheid variable star over two cycles of variations; one cycle is enhanced in the middle on white background. The figure illustrates increasing amplitude in variability towards bluer wavelengths, rightward shift in peak brightness towards redder wavelengths, and anticorrelation of radial velocity and change in radius to brightness and colour. The figure has been adapted from real observations in Burki (1985) and Madore & Freedman (1998).*

Classical Cepheids are massive stars and hence relatively young. Consequently they are only found in late-type spiral and irregular galaxies in regions of recent star formation. Initially stars produce energy in fusion reactions in the hydrogen burning core. Once hydrogen is exhausted a star evolves off the main-sequence and moves rapidly across the Hertzsprung–Russell (HR) diagram to the region called the giant branch. Stars then begin to burn helium and move back to higher temperature. This second crossing of the Hertzsprung–Russell diagram proceeds much slower and the star may spend a significant time in the so-called “instability strip”. The cause of instability for Cepheids is believed to be in the changing atmospheric opacity with temperature in the helium ionization zone. This zone alternately traps and releases energy, thereby periodically forcing the outer layers of the star into motion against the restoring force of gravity (Madore & Freedman 1998).

All stars produce light in proportion to both their area ($4pR^2$) and the surface brightness over that area ($s\,T_{eff}^4$). Their bolometric luminosities L are defined by Stefan’s law

$$L = 4p\,R^2 s\,T_{eff}^4 \tag{3.2}$$

where R is the radius and T_{eff} the effective surface temperature of the star, and s is the Stefan–Boltzmann constant (5.6697 × 10^{-8} W m^{-2} K^{-4}). Luminosity is thus proportional to the second power of radius and fourth power of temperature of the star. During a pulsation, most of the Cepheid variation in luminosity is due to changes in temperature with only comparatively small changes in radius (Tanvir 1997).

Feast and Walker (1987) have calibrated a relation between period, luminosity and colour for Cepheids, all at the same distance, in the LMC. The effective temperature can be substituted by an observable unreddened colour $(B-V)$ and Stefan’s law, expressed in magnitudes, can be written in the form

$$M_V = a\ \log P + b\left(B-V\right)_0 + g \tag{3.3}$$

where a, b and g are coefficients, which may further depend on the chemical composition of the Cepheids in question. Representative values of these coefficients measured for the Small and Large Magellanic Cloud are given by Feast and Walker (1987) as follows: $a = -3.53$, $b = 2.13$ and $g = -2.13$ (observed values being $-1.8 < g < -2.7$). Called the period–luminosity–colour (PLC) relation for Cepheids, the relation was discovered and explained by Sandage (1958), Sandage & Gratton (1963) and Sandage & Tammann (1968).

Another approach to the Cepheid magnitudes uses a simplified period–luminosity (PL) relation. Ignoring the colour term results in larger dispersion of the relation about the mean, but is simpler observationally. The range of the colour term, $(B–V)_0$, at a given period is about 0.32 (Caldwell & Coulson 1986) for Cepheids of a given composition. The range is smaller for other colours due to their smaller amplitudes in all other bands in comparison with the B-band. Although determining period becomes increasingly difficult as amplitude decreases towards longer wavelengths, the reduced dispersion of the period–luminosity relation increases the accuracy of the absolute magnitude measurements. Furthermore, distance to a galaxy can, and should, be determined using a large number of Cepheid measurements. The error in the mean distance modulus decreases by the square root of the number of individual distances, resulting in an accuracy of 10%

(or 0.2 mag in true distance modulus) with two to three dozen Cepheids (Madore & Freedman 1998).

Freedman and Madore (1988) present period–luminosity relations adopted from totally self-consistent measurements of 32 LMC Cepheids

$$M_B = -2.43(\pm 0.14)\,(\log P - 1.00) - 3.50(\pm 0.06) \qquad [\pm 0.36] \tag{3.4}$$

$$M_V = -2.76(\pm 0.11)\,(\log P - 1.00) - 4.16(\pm 0.05) \qquad [\pm 0.27] \tag{3.5}$$

$$M_R = -2.94(\pm 0.09)\,(\log P - 1.00) - 4.52(\pm 0.04) \qquad [\pm 0.22] \tag{3.6}$$

$$M_I = -3.06(\pm 0.07)\,(\log P - 1.00) - 4.87(\pm 0.03) \qquad [\pm 0.18] \tag{3.7}$$

where period is given in days. The LMC data set was chosen because of its large sample size, large wavelength coverage and because the LMC is very close to being face-on, thereby minimizing the effects of back-to-front geometry on the solutions. Cofficients are given with errors, in parentheses, following the values. The root-mean-square dispersion about the mean is shown for each period–luminosity relation in square brackets.

The absolute calibration of the Cepheid period–luminosity relation is based on a small number of Cepheids found in galactic star clusters (Fernie & McGonegal 1983). These clusters have independent distances from main-sequence fitting and trigonometric parallaxes. Unfortunately the statistics are poor and the intrinsic luminosities and colours of many of the cluster Cepheids are still uncertain. Indeed, Hipparcos data suggests that this calibration may require adjusting in the future (Feast & Catchpole 1997) although some comparisons to earlier ground-based calibrations do not support this conclusion (Sandage & Tammann 1998). The GAIA mission will measure trigonometric parallaxes for a large number of Cepheids in the Milky Way and thus eliminate virtually all systematic errors in Cepheid distances (Tammann & Reindl 2002).

Determining a distance to a galaxy using Cepheids involves (1) aquisition of observations over several epochs, (2) identifying variable objects in the observed field, (3) deriving magnitudes of these objects, (4) determining their periods, (5) calculating their mean magnitudes and colours on a standard system, and (6) correcting for absorption.

Step (1) requires some background knowledge of the galaxy in question. Some kind of initial distance estimate is recommendable for a reasonable estimation on exposure time per epoch. If the exposure time is too short Cepheids will not be visible in the images, i.e. will be dwarfed by background fluctuations. If the galaxy is too distant no amount of exposure time will yield Cepheids because they become blended into the background galaxy. Presently the practical distance limit is about 42 Mpc (Freedman et al. 1997). It is also important to have an idea on observable periods. Brightest Cepheids have the longest periods and for any given distance there is a minimum detectible period. All Cepheid work requires observations through several epochs. In optimal case it is possible to obtain data on a number of epochs over a time period lasting from the shortest observable Cepheid period to a couple of hundred days. Cook et al. (1986) have demonstrated that in the best case of optimal scheduling and high signal-to-noise photometry only eight epochs are required. To identify new Cepheids in a galaxy with only a crude distance estimate, the number of epochs has to be significantly higher and should sample at least a significant fraction of light curve amplitude.

Identification of variable objects, step (2), is possible by blinking images obtained at two epochs – preferably with several pairs of epochs – and searching for variability visually. While a relatively straightforward and fast way of identifying variables, visual identification fails with faintest objects and those in close vicinity of other sources of luminosity; stars, clusters and nebulae. In the era of computers one can search for variables automatically with software, which identifies all point sources and measures their luminosities over all observed data. Even this method fails with the faintest sources and variables in crowded areas of the image. The best, and most time-consuming, way to find variables is to locate all point sources visually and then automatically find their luminosities over all epochs. By definition most Cepheid observations are made in crowded fields; in nearby galaxies that cover most of the CCD frame with a multitude of stars. In such crowded fields it is virtually impossible to find areas free from some luminosity arising from the galaxy itself. A good example of how sophisticated crowded field photometry has become is given by Gössl and Riffeser (2002). The photometry software used to identify point sources and select variables automatically yields instrumental magnitudes for detected or suspected variable objects – step (3).

Once magnitudes are measured for each epoch, it is possible to construct a light curve for each measured object. Variation significantly in excess of the photometric errors now marks the object as a variable star. Period-fitting algorithms may be employed to find a period for sparsely obtained data (e.g. Lafler & Kinman 1965, Tifft 1997) and it is relatively simple to identify the Cepheid from the shape and amplitude of the light curve – step (4).

True apparent magnitudes, step (5), are essential for Cepheid distances and the instrumental magnitude must be calibrated to standard stars of known brightness.

In the simplest case, galactic absorption, step (6), may be obtained from extinction maps such as those due to Burstein & Heiles (1984) or from Schlegel et al. (1998). It can also be estimated from observations over several bandpasses of the field under study. The estimated extinction should be included in the distance modulus equation (3.1) to correct for global reddening.

3.2 Planetary Nebula Luminosity Function

Planetary nebulae (PNe) are expanding shells of highly ionized gas ejected by stars, of the order of a few solar masses, during their last major phase of nuclear burning as red giants prior to becoming white dwarfs. The contracting central stars are extremely hot with luminosities comparable to the brightest red supergiants. Most of their radiation is in far ultraviolet rendering them faint in visible wavelengths. However, their surround-

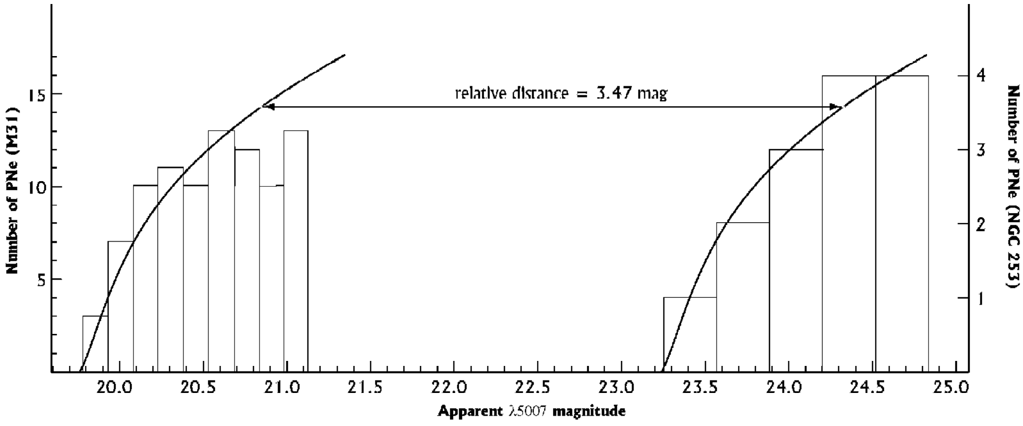

Figure 3.2: *Comparison of observed and theoretical planetary nebula luminosity functions. Solid curve is the theoretical PNLF from Eq. 3.8 (Ciardullo et al. 1989). The histograms show the PNLF constructed from observed PNe; Andromeda Galaxy from Jacoby et al. (1992) on the left and NGC 253 from paper II of this thesis on the right. The two histograms have been normalized to the same area. Note that the number of PNe, N, is shown here, not log(N) as is often the case. The NGC 253 distance was found to be 27.73 magnitudes assuming an Andromeda Galaxy distance of 24.42 magnitudes.*

ing nebulae reprocess the extreme ultraviolet (EUV) into discrete emission lines. With fading central stars and expanding nebulae the planetary nebulae have lifetimes of a few tens of thousands of years before becoming too faint to be detected.

Planetary nebulae are not associated with any one stellar population. Therefore they are found in galaxies of all Hubble types. They tend to originate from long lived stars that have had time to develop high inclination orbits in their galaxies. This means there are planetary nebulae well above the disk, where the dust content is highest, away from crowded star-forming regions (Jacoby et al. 1992).

Identification of planetary nebulae is straightforward as their emission lines can be seen with special narrow-band filters with little fear of contamination from continuum sources. They only need to be observed once, unlike the variable objects of other distance measuring methods. They are sufficiently abundant in large galaxies that one can construct a well defined planetary nebula luminosity function (PNLF) fairly easily (Jacoby et al. 1992).

The use of planetary nebulae for distance indicators originates from Hodge (1966) but was not applied before Ford & Jenner (1978), who used the [O III] λ5007 filter to detect the brightest optical emission line planetary nebulae produce. Jacoby (1980) showed that the [O III] λ5007 luminosity function for faint planetary nebulae can be modelled in a straightforward manner as a luminosity decline in each planetary nebula due to a uniformly expanding shell with a nonevolving central star (Henize and Westerlund 1963).

Later Ciardullo et al. (1989) added a cutoff exponential and presented the currently used function

$$N(M) \propto e^{0.307M}\left(1-e^{3(M^{*}-M)}\right) \tag{3.8}$$

where M^* is the absolute magnitude of the most luminous planetary nebula and the observed planetary nebula have magnitude, M, given by the λ5007 flux, F_{5007}, as

$$M = -2.5\log\left(F_{5007}\right) - 13.74 \tag{3.9}$$

Fig. 3.2 illustrates the theoretical and observed planetary nebula luminosity functions for two systems, M31 and the one studied in this thesis, NGC 253.

Ciardullo et al. (1989) used planetary nebulae in the Andromeda Galaxy to set the zero point of the distance scale. Adopting a Cepheid based distance of 710 kpc ($m-M$ = 24.26 mag), which implies a distance of $m-M$ = 18.34 mag for the Large Magellanic Cloud (LMC), and using the relative distance between them as determined from Cepheids by Freedman & Madore (1990), they found the best-fit value for the brightest planetary nebula to be $M^* = -4.48^{+0.036}_{-0.046}$.Current estimates of the distance of the Andromeda Galaxy suggest a couple of tenths of a magnitude higher value (e.g. Brown et al. 2004). The correction may be applied to the M^* value or made after the planetary nebula luminosity function distance has been calculated for a galaxy. Nevertheless, the value $M^*=-4.48$ is in widespread use in the literature and the correction due to the differing Andromeda Galaxy distance modulus is generally applied to the final distance modulus of the target galaxy.

The planetary nebula luminosity function is, if not universal, at least insensitive to effects such as galaxy colour, metallicity and Hubble type (Jacoby et al. 1992). The zero point also seems to be constant in different galaxies even though their surface brightnesses and metallicities vary (Jacoby et al. 1992). A comparison between Cepheid and planetary nebula luminosity function distances for a large number of galaxies within a range of ≈20 Mpc shows excellent agreement (Jacoby 1997) and thus establishes the planetary nebula luminosity function method amongst the most accurate distance measuring methods currently available; along with Cepheids, surface brightness fluctuations and tip of the red giant branch (see chapters 3.1, 3.3 and 3.4.5).

The method is sensitive to contaminating objects such as cosmic rays and detector anomalies (Jacoby et al. 1990). The physics behind the rapid cutoff at the bright end of the planetary nebula luminosity function is also poorly known. There is no proper explanation as to why the cutoff is insensitive to the metallicity or age of the stellar population (Jacoby et al. 1992).

In practice planetary nebulae are observed with [O III] λ5007 filter, with a full width at half maximum bandpass of approximately 30 Å. Planetary nebulae redshifted onto the filter wings by the velocity dispersion of the galaxy may be rendered invisible in filters that are much narrower than that; e.g. a galaxy at 8.5 Mpc has a cosmological redshift of 10 Å rendering filters of <20 Å a poor choice if one wants to use the same wavelength out to 10 Mpc or so – galaxies even closer than that with high outward peculiar velocities exhibit the same behaviour. Broader filters collect too much continuum light from the host galaxy and degrade the signal-to-noise ratio of the planetary nebulae.

The simplest method to identify planetary nebulae is to observe with another narrow-band filter a couple of hundred ångströms off the [O III] λ5007 bandpass (Jacoby et al. 1992). Planetary nebulae should be completely invisible in the other bandpass and blinking the two images reveals them easily – in theory. Unfortunately, for planetary nebulae in the inner parts of galaxies a bright and rapidly varying background makes the blinking technique cumbersome. The situation improves considerably if the off-band image is simply subtracted from the [O III] λ5007 image. Instead of the off-band image a continuum image may also be used, with care, as the planetary nebulae are very faint in the continuum. This has an additional advantage in the identification of other sources on the image, and is the method used in this thesis. The practical aspects of making observations for the planetary nebula luminosity function method are well described in Jacoby et al. (1992).

Special attention has to be paid when the planetary nebula luminosity function method is used with late-type galaxies; i.e. spirals and irregulars. Especially at large distances compact H II regions may be confused for planetary nebulae. However, while H II regions emit light in [O III] λ5007 they generally do so also in Hα, which is not the case with planetary nebulae. Therefore a simple distinction between the two is that if the object is visible in the [O III] λ5007 image, absent on a continuum image and absent or extremely weak in an Hα image, it is most likely a planetary nebula. Some H II regions are also faint in Hα and since there are lots of them in late-type galaxies, the only absolute way to discriminate between the two object types is to measure their sizes or luminosity profiles. Beyond around 2 Mpc planetary nebulae always appear stellar, even with the diffraction-limited Hubble Space Telescope (Jacoby et al. 1992). H II regions are much larger and can be resolved to distances of approximately 15 Mpc.

Another possible source of confusion arises from dust in disks and spiral arms of spiral galaxies. However, because a sufficient number of planetary nebulae should always be sited well above the disk, a good luminosity function is produced, as argued in paper II of this thesis.

Once the planetary nebulae of a galaxy have been identified and their magnitudes measured, a luminosity function may be derived. A comparison of the luminosity function to that from Eq. 3.8 yields the distance of the galaxy. This method has been applied to the galaxy NGC 253 in paper II of this thesis.

3.3 Surface Brightness Fluctuations

The surface brightness fluctuation (SBF) method was introduced by Tonry & Schneider (1988) to measure distances to high surface brightness giant elliptical galaxies. The method relies on measuring the luminosity fluctuations that arise from the counting statistics of the stars contributing to the flux in each pixel of a high-signal-to-noise CCD image of a galaxy. As shown by Tonry and Schneider (1988), the amplitude of these fluctuations is inversely proportional to the distance of the galaxy. This remarkable result permits distances to be measured out to at least 16 Mpc, with 2.5 metre class telescopes, as demonstrated in paper III of this thesis. Tonry (1997) gives 200 Mpc as the upper limit for the feasibility of the method.

Fig. 3.3 illustrates the surface brightness fluctuation method with a comparison of two distances. The same galaxy is shown at a distance of 10 Mpc (Fig. 3.3.a) and 5 Mpc (Fig. 3.3.f). Imagine selecting a square area on the galaxy with the exact same selection of stars on both images (white squares on Figs. 3.3.a and 3.3.f). A representation of stars contained in the selected area is shown in Figs. 3.3.b and 3.3.g. Because the physical area of a fixed angular size increases as distance squared (d^2) our selected area falls on 3×3 pixels in the more distant case and on 6×6 pixels in the closer case. The pixels are outlined as a grid on Figs. 3.3.b and 3.3.g and the light they gather from all the stars in each of the grid cells is shown in Figs. 3.3.c and 3.3.h. These subfigures show the real CCD pixels – the information we can extract from the selected area of the galaxy under study.

As can be seen in this example, individual stars are not resolved on the CCD image, but their light nevertheless leads to luminosity fluctuations in the individual CCD pixels. The stars are not homogeneously distributed in any galaxy and there is always some fluctuation in surface brightness. The further away we look, the more stars contribute to the light of any individual CCD pixel and, because of averaging, the smoother the surface looks. For this reason, the surface brightness alone can not be used as a measure of distance. As the number of stars projected into a pixel increases, with the observed pixel area, as distance squared (d^2), the flux per star decreases as an inverse of distance squared (d^{-2}). Hence the mean brightness of a pixel stays the same.

To calculate the distance of a galaxy, representative fields are selected from the surface of the galaxy avoiding contaminants such as foreground stars, globular clusters and dust. These fields are typically rectangular and contain a few hundred pixels. A Fourier transform and azimuthally averaged power spectrum is determined for them to measure the power spectrum components, which are then used to calculate the apparent stellar fluctuation magnitude of the field. Power spectra of our example galaxy at two distances are shown in Figs. 3.3.d and 3.3.i. The point-spread-function (PSF) power spectrum $P_0 \times \mathrm{PS}_{\mathrm{star}}(k)$ is shown as a dotted line falling down from the vertical axis and an additive constant P_1 is shown as a horizontal dotted line. An indication to the distance difference can be seen in the less pronounced power spectrum in Fig. 3.3.d and higher relative noise in the horizontal part of the data.

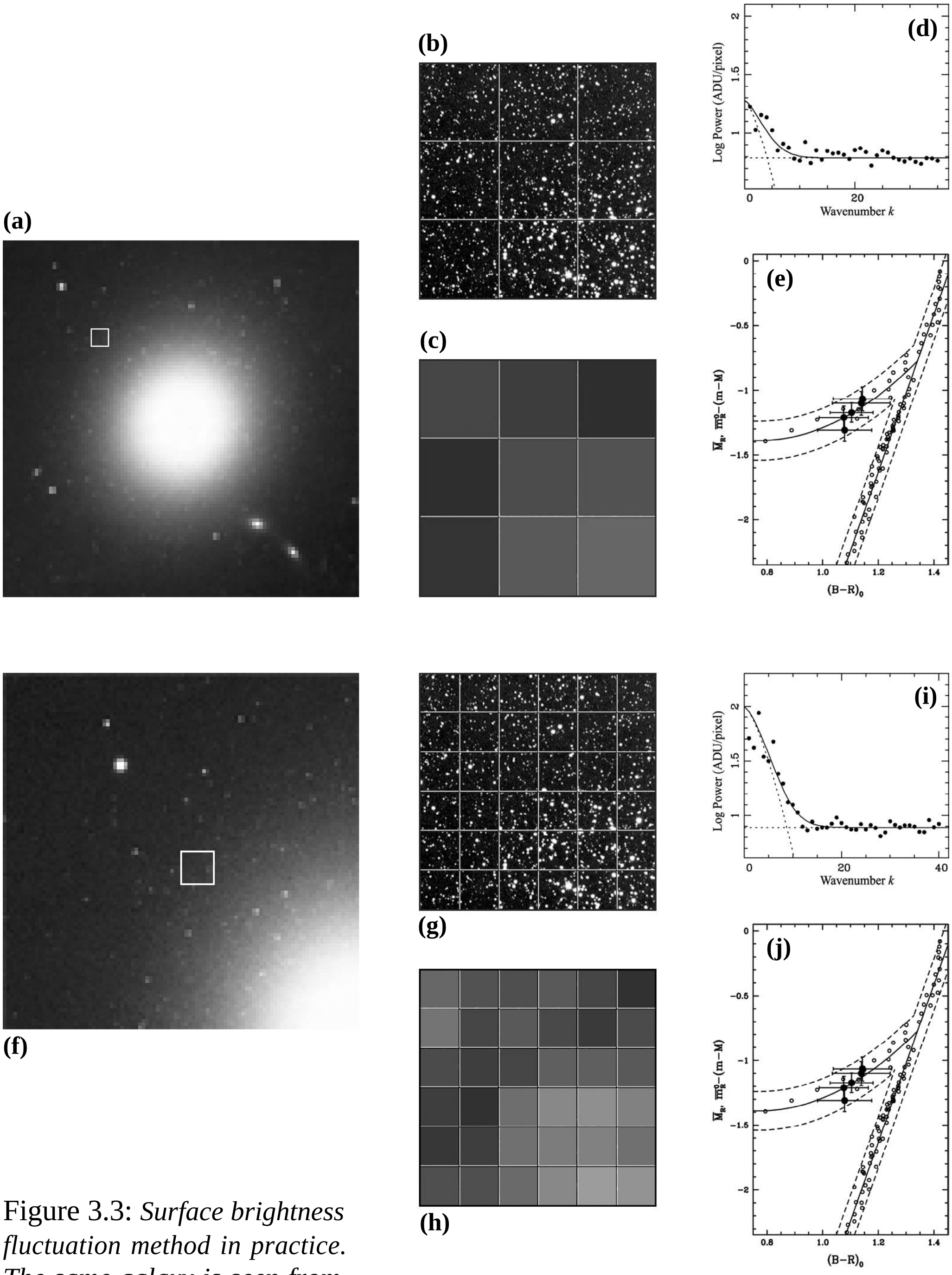

Figure 3.3: *Surface brightness fluctuation method in practice. The same galaxy is seen from distances of 10 Mpc (a) and 5 Mpc (f). The same stars are seen in an array of 3×3 pixels (b, c) in the more distant case and in an array of 6×6 pixels (g, h) in the closer case. The resulting power spectra of pixel brightness (d, i) show a difference between the two cases in both signal-to-noise and power. The final fit requires a shift of 30.0 magnitudes for the more distant case (e) and a shift of 28.5 magnitudes for the closer case (j).*

The surface brightness fluctuation method has been applied only recently to dwarf elliptical galaxies (Jerjen et al. 1998). Prior to empirical calibration of the surface brightness fluctuation method for dwarf elliptical galaxies, a theoretical calibration was used via synthetic stellar population models. Jerjen et al. (2000) used Worthey's (1994) models combined with Padova isochrones (Bertelli et al. 1994). A theoretical relationship between absolute fluctuation magnitude and the stellar population's integrated $(B-R)$ colour was computed first for stellar populations with a variety of ages and metallicities; stars with ages of 8, 12 and 17 Gyr each divided into eleven groups with metallicities ranging from [Fe/H] = –1.7 to [Fe/H] = 0.0; and then for the same populations mixed with solar type populations in a variety of mass fractions; 5 Gyr old solar metallicity populations were introduced as 10%, 20% and 30% of the total stellar mass in the calculations. In each case two distinct branches are visible in the fluctuation versus colour diagrams (see Figs. 3.3.e and 3.3.j.). Jerjen et al. (2000b) identified these branches as the red, linear branch with old, metal-poor stellar populations and the blue, parabolic branch with younger, more metal-rich, and mixed stellar populations. In paper I of this thesis the theoretical relationship was calibrated with three dwarf elliptical galaxies using good tip of the red giant branch distances and measuring the mean difference to our surface brightness fluctuation distances as the required correction. As a result, the absolute mean R-band magnitude in the parabolic branch was found to be

$$\bar{M}_R = 1.89\left[\left(B-R\right)_0 - 0.77\right]^2 - 1.39 \tag{3.10}$$

where $(B-R)_0$ is the colour term. Similarily, as established by Jerjen et al. (2000b) the mean R-band magnitude for the linear branch may be calculated by

$$\bar{M}_R = 6.09\left(B-R\right)_0 - 8.78 \tag{3.11}$$

Using the appropriate one of these equations, depending on the measured colour distribution of several fields in each galaxy, and the apparent stellar fluctuation magnitudes, distances of the galaxies can be calculated. Results from many small fields on the galaxy can then be fitted with the abovementioned theoretical relationship as has been done with our example galaxy (Figs. 3.3.e and 3.3.j). The true colour and absolute magnitude of a galaxy remain the same regardless of where it is observed from. This is the reason why these subfigures are identical. However, in reality various sources of errors and uncertainty would enhance the variance of individual measurements from different fields but the average should remain the same. The real distinction between the two cases in this example is the 1.5 magnitude difference seen in the apparent magnitude.

Due to the nature of the surface brightness fluctuation method, it is applicable to systems that are relatively smooth. It has been usefully applied to elliptical and lenticular galaxies, bulges of spiral galaxies and globular clusters (Jacoby et al. 1992, Tonry 1997).

Observations should be made with sufficiently long exposure times to aquire signal-to-noise high enough for data to be dominated by star-counting statistics rather than photon-counting statistics. It turns out that ten counts per giant is an excellent rule of thumb to obtain an appropriate signal to noise (Jacoby et al. 1992, Jerjen et al. 1998). In practice this means that exposure times at 2.5 metre class telescopes are tens of minutes to achieve optimal signal-to-noise ratio for galaxies in the observable range of the method. An example galaxy is very illustrative here. In paper III of this thesis a distance was measured to NGC 4150 using six fields on the galaxy surface. Typical surface brightness of these fields if around 26 magnitudes per square arc second. We have 0.035 square arc second pixels, which yields a surface brightness of 29.5 magnitudes per pixel. The distance modulus to this galaxy turns out to be 30.8. Pixels with apparent surface brightness of 29.5 magnitudes then have an absolute surface brightness of –1.3 mag, corresponding to about one giant per pixel. There are about 13 counts in the mean on the Nordic Optical Telescope images, therefore there are in the order of ten counts per giant in this example.

Comparison to other distance measuring methods (e.g. Tonry 1997) shows that correlation between surface brightness fluctuation distances and especially Cepheid and type II supernova distances is remarkably good with under 0.05 magnitude offsets. Since internal errors of the method are also quite small, especially at moderate distances, surface brightness fluctuation method can be considered as one of the primary extragalactic distance measuring methods.

3.4 Other distance measuring methods

Distances have been measured using three specific techniques in this thesis. Many others exist and are very briefly described below. Several of these have been applied to the galaxies in our sample, and are discussed with reference to our own distance measurements in each of the papers. These are also the most often used techniques to obtain distances within the Extended Local Group as seen in Appendix B.

3.4.1 RR Lyrae

RR Lyrae stars, also known as short period Cepheids, are old low-mass variable stars that pulsate with periods shorter than one day. Though otherwise similar to classical Cepheid variables, RR Lyrae variables are several magnitudes less luminous. Their small range of absolute magnitudes, $M_V = 0.77 \pm 0.15$ (Fernley et al. 1998), makes them useful as distance indicators, though limits their usefulness to a few megaparsecs. For further information see a review by Pritchet (1988).

3.4.2 Novae

Several types of novae belong to cataclysmic variables, which are binary systems with one member being a white dwarf star. The objects undergo prominent and rapid outbursts, usually at irregular intervals and then fade quite slowly over a timespan of years to decades. Using the rate of their luminosity decline over the first two magnitudes from the maximum luminosity, their absolute magnitude can be established. For further information see a review by Jacoby et al. (1992).

3.4.3 Supernovae

Type Ia supernovae are widely used distance indicators, achieving particularly exciting results in the high-redshift supernova programs (Perlmutter et al. 1999). They are thought to originate from the supernova explosion of an accreting white dwarf in a binary system. Type II supernovae may also be used to calculate distances if the luminosity and expansion velocity of the supernova remnant can be measured, leading to a physical distance. For further information on type Ia supernovae see a review by Jacoby et al. (1992) and on type II supernovae see Schmidt et al. (1994).

3.4.4 Globular clusters

Globular clusters contain in the order of 10^5–10^6 metal weak stars. Beyond a few megaparsecs individual stars are not resolved and globular clusters appear more or less point-like. The globular cluster luminosity function peaks at about $M_V = -6.5$ and has a width of about ten magnitudes. Once enough globular clusters are observed to form a luminosity function, the apparent peak value may be identified. Using this, empirical calibration for the absolute magnitude and any necessary correction for foreground reddening, the distance modulus can be calculated. For further information see a review by Jacoby et al. (1992). We compare a globular cluster luminosity function distance to NGC 253 planetary nebula luminosity function distance in paper II of this thesis.

3.4.5 Tip of the red giant branch

The tip of the red giant branch method is based on well understood stellar evolution of a post-main-sequence low-mass star up the red giant branch. The luminosity and core temperature of such a star increase with time until the core temperature reaches a limit at which helium in the core ignites. The resulting core flash reduces dramatically the temperature and luminosity of the star, removing the star from the red giant branch of the colour-magnitude diagram. This can be seen as the tip of the red giant branch (TRGB), which has a well calibrated absolute magnitude of $M_I = -4.05$ (Karachentsev et al. 2003). The apparent magnitude of the TRGB is usually measured using an edge-detection Sobel filter introduced by Lee et al. (1993). Distances for dozens of galaxies within a few megaparsecs have recently been compiled. They make a very useful and uniform database for comparison with other techniques. Our own planetary nebula luminosity function distance for NGC 253 compares favourably with a tip of the red giant branch distance (paper II). For further information see a review by Madore and Freedman (1998).

3.4.6 Brightest stars

A correlation of the luminosity of the few brightest blue and red stars to the luminosity of their parent galaxy was found by Sandage and Tammann (1974b). Assuming the observed stellar population is not seriously incomplete, the distance can be calculated using this correlation to establish the absolute magnitude of the galaxy and hence the distance modulus to it. For further information see a review by Georgiev et al. (1997).

3.4.7 H II regions

A correlation of H II region diameters and the luminosity of their host galaxies has been found by Gum and de Vaucouleurs (1953). This correlation depends also of the luminosity class of the galaxy. Once the luminosity class has been determined and H II region diameters have been measured, a distance can be derived. Lately this method has been replaced better methods such as the tip of the red giant branch, surface brightness fluctuation and planetary nebula luminosity function methods. For further information see a review by Melnick (1988), and Sandage and Tammann (1974a).

3.4.8 Faber-Jackson or D_n-s relation

The Faber-Jackson relation for elliptical galaxies uses the relationship between luminosity and central velocity dispersion of elliptical galaxies as a distance indicator. The original Faber-Jackson relation was found to have an uncertainty of 32% (Tonry & Davis 1981) and a new, improved D_n-s relation was introduced by Dressler et al. (1987). They incorporated both luminosity and surface brightness into a single parameter, which decreased the uncertainty to approximately 20% (Jacoby et al. 1992) for individual galaxies. Group distances can be measured more accurately with a large number of galaxies. For further information see a review by Jacoby et al. (1992).

3.4.9 Tully-Fisher relation

The Tully-Fisher relation uses the empirical relationship between the luminosity of a spiral or irregular galaxy and its rotational velocity, measured in the neutral hydrogen (H I) spectral line wavelength of 21 centimetres, to measure distances. The method was introduced by Tully and Fisher (1977) and an extensive review can be found in Jacoby et al. (1992).

3.4.10 Redshift

Redshift is a means of obtaining a rough distance in the absence of direct distance measurements. If the redshift, or velocity, of the galaxy is known the distance may be calculated as

$$D = \frac{V}{H_0} = \frac{cz}{H_0} \tag{3.12}$$

where D is the distance, V the recession velocity, z the redshift, c the speed of light, and H_0 the Hubble constant, currently believed to be 71^{+4}_{-3} km s^{-1} Mpc^{-1} (Spergel et al. 2003). Due to peculiar velocities this is a very inaccurate means to establish distances, but may give an indication for or against group membership.

3.4.11 Yet other methods

Appendix B lists 580 distance measurements to almost all Extended Local Group galaxies and suspected members, some of which have distance estimators based on one or more of the following objects or techniques: horizontal branch stars (see e.g. Caloi et al. 1997), tip of asymptotic giant branch (see e.g. Davidge & van den Bergh 2001), colour-magnitude diagram (see Vorontsov-Vel'yaminov 1987), brightest supergiants (see e.g. Tully & Nakashima 1986), angular sizes of ring structures (see Vorontsov-Vel'yaminov 1987), carbon stars (see e.g. Ventura et al. 1999), eclipsing binaries (see Guinan 2004), Mira variable stars (see Vorontsov-Vel'yaminov 1987), luminosity class (see e.g. de Vaucouleurs 1986), angular sizes of galaxies (see Vorontsov-Vel'yaminov 1987), and appearances of galaxies (see Vorontsov-Vel'yaminov 1987).

CHAPTER 4

Distances in nearby galaxy space

The contents of nearby space, especially the groups of galaxies surrounding the Local Group, is of considerable interest. Not only can we make accurate measurements to galaxies out to 10–20 Mpc, but also map the measurements into a coherent picture of the structure and workings of the matter in nearby space. We still have open questions on the distribution and amount of dark matter. We have a new riddle of the dark energy in our hands. True distances to nearby galaxies are in more demand than ever!

4.1 Distances to dwarf elliptical galaxies (Paper I and Paper III)

Bright and massive galaxies are well studied out to ≈10–20 Mpc. However, within the last decade a whole new class of objects, the dwarf elliptical galaxies, has been detected and identified surrounding the massive galaxies in abundance (Côté et al. 1997, Karachentseva & Karachentsev 1998, Jerjen et al. 2000a). These galaxies offer considerable scope to map out the structure of the Extended Local Group and beyond – without them we would be restricted to the handful of bright galaxies.

A distance measuring method well suited for measuring distances to elliptical galaxies, dwarf or giant, is the surface brightness fluctuation method (as described in chapter 3.3). Once the existence and class of these galaxies is established it is relatively straightforward to utilize the method to obtain their distances. As described in papers I and III of this thesis, distances to fifteen dwarf ellipticals and one lenticular galaxy, were measured using the surface brightness fluctuation method. Distances to dwarf ellipticals can also be obtained via the colour–magnitude diagram, the tip of the red giant branch magnitude or RR Lyrae stars, but the requirement of resolving the galaxy into stars makes these methods difficult and time-consuming. We have demonstrated that the surface brightness fluctuation method is very efficient for these studies.

Mapping the dwarf elliptical galaxies in nearby groups was began by Jerjen and collaborators. They developed a version of surface brightness fluctuation method especially suited for dwarf ellipticals (Jerjen et al. 1998). It was then calibrated with observations to galaxies with previously known distances (paper I of this thesis). The dwarf ellipticals discovered by deep galaxy surveys of Côté et al. (1997) and Karachentseva & Karachentsev (1998) have been the target of a programme of surface brightness fluctuation distance measurements by Jerjen and collaborators.

In paper I we used independently measured tip of the red giant branch distances to DDO 44, KK98 77 and DDO 71 to calibrate the distance scale of our surface brightness fluctuation method. The surface brightness fluctuation distances obtained for them were used to calibrate the equation used to calculate absolute magnitudes of the parabolic branch of stellar populations in these galaxies. The change was +0.13 magnitudes and the corrected form of the formula is presented as Eq. 3.10 on page 25 of this thesis. Prior to our study the surface brightness fluctuation scale was calibrated from theoretical models, combining Worthey's (1994) models with the Padova isochrones (Bertelli et al. 1994).

Three further dwarf ellipticals; UGC 4998, DDO 113 and UGC 7356; had first distance measurements ever, as reported in paper I.

Ten more distances were obtained in paper III. Galaxies KDG 61 and UGC 5442 had extant distance estimates via the tip of the red giant branch method by Karachentsev et al. (2000). Our surface brightness fluctuation distances agree with these distances within 0.1 magnitudes – less than the error limits of either study. The same applies with the earlier SBF distance to NGC 4150 and an earlier, but tentative, distance to UGC 7639 measured from the brightest blue and red stars. Completely new distances were provided for galaxies UGC 1703, UGCA 200, UGC 5944, and UGC 8882.

The surface brightness fluctuation distances to these galaxies confirmed earlier speculations of group memberships of KDG 61 and UGC 5442 in M81 group (Karachentsev et al. 2000), UGC 7639 in Canes Venatici II cloud (Makarova et al. 1998), BTS 128 in Coma I group (Binggeli et al. 1990), UGC 5944 in Leo I group (Ferguson & Sandage 1990) and UGC 8882 in M101 group (Bremnes et al. 1999). A vague speculation of NGC 4150 being in the outskirts of Virgo cluster (Karachentsev et al. 2003b) was confirmed by us. Also UGC 8799 was found to be a likely member of the Virgo cluster. UGCA 200 was found to be too near to be physically connected to NGC 3115, as thought previously (Tonry et al. 2001), and connection of UGC 1703 with NGC 925 was found to be unlikely with NGC 784 being a more likely companion to the galaxy.

All the new distances were consistent with existing distances and velocities providing further confidence in the surface brightness fluctuation method. Distances ranged from three to sixteen megaparsecs, which indicated the method can well be used at least within this range with a 2.5 metre class telescope and with tolerable errors even further away. The distance measurement programme continues with an aim at obtaining more accurate distances using the European Southern Observatory (ESO) Very Large Telescope (VLT).

4.2 Distance to NGC 253 (Paper II)

The Sculptor group of galaxies is one of the neighbouring groups thought to share some dynamical history with the Local Group (McCall 1989, Byrd et al. 1994). What was originally perceived as the Sculptor group has turned out to be a long stream of galaxies with at least three major concentrations (e.g. Whiting 1999). The NGC 24 / NGC 45 concentration has been found to be at least six megaparsecs distant and the nearer galaxies are divided into concentrations around the spiral galaxies NGC 300 and NGC 253.

The most massive of these galaxies, NGC 253, is of considerable interest. If it is as far away as some distance estimates place it, it is at least as large as the Milky Way (de Vaucouleurs 1983, Lauberts & Valentijn 1989). If it is at the nearer end of distance estimates, it clearly may have been involved in Local Group dynamics (Byrd et al. 1994). The galaxy is well known for the heavy obscuration by dust in the optical images (Jarrett et al. 2003). It is one of the closest large starburst galaxies to us and is a prominent X-ray source (e.g. Pietsch et al. 2000). Infrared studies have revealed NGC 253 to be a barred spiral of type SAB(5)c, starburst (Jarrett et al. 2003). Very few distance estimates existed before our study.

The location of NGC 253 near the south galactic pole means there is only a little galaxtic extinction involved but its extreme internal extinction may have been a primary cause for reluctance in obtaining a Cepheid distance to it. Our approach, described in detail in paper II of this thesis, of measuring the distance using the planetary nebula luminosity function (chapter 3.2) is more advantageous in a dusty enviroment. We demonstrated through Monte-Carlo simulations that the planetary nebula luminosity function, and particularly its bright end, are very little affected by even quite large amounts of dust. At least a considerable fraction of planetary nebulae lie above the dusty disk region of the galaxy and a sufficient number of planetaries can be seen, with little or no effect from internal extinction, to build a representative luminosity function. The effects of dust were carefully studied in the paper and were found to be both well understood and small considering the measurement of distance using the planetary nebula luminosity function.

Our distance was found to agree well with existing distances by other methods: tip of the red giant branch and globular cluster luminosity function – once a common zero-point was adopted for all distance scales. Using all these distances, with appropriate weighing, we calculated the true distance modulus of NGC 253 to be 27.8 ± 0.1 mag, corresponding to a distance of 3.6 ± 0.2 Mpc. This distance is clearly large enough for NGC 253 to have played no significant rôle in Local Group dynamics.

4.3 Distance to IC 342 (Paper IV)

Another, even more important, group suggested as having a common dynamical history with the Local Group is the IC 342 / Maffei group of galaxies (McCall 1989, Byrd, 1994). The group is located behind the zone-of-avoidance and was therefore not studied much before the 1990's. The large elliptical galaxy Maffei 1 and its considerably large companion, the barred spiral galaxy Maffei 2, were only discovered in 1968 by Paolo Maffei. The other large galaxy in the group, IC 342, was known by that time, but its size and proximity began to be unravelled only recently (McCall 1989).

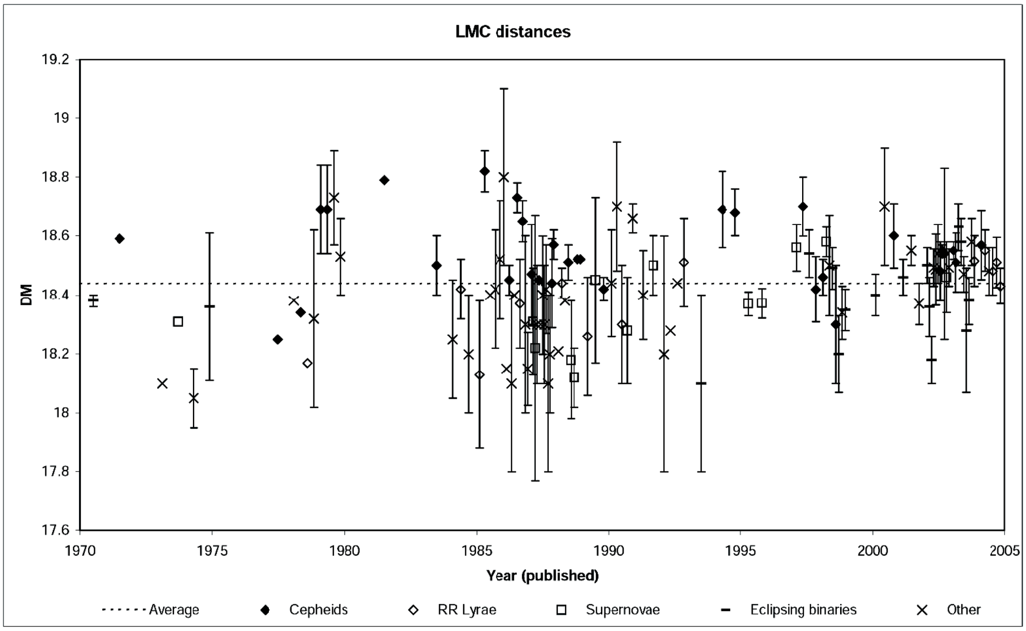

Figure 4.1: *Distances of the Large Magellanic Cloud from table B.1 in appendix B. Overall there are 119 distance measurements, of which 83; all within one sigma of the overall average; have been used to calculate the depicted average distance modulus of 18.44 mag. All distance measuring methods with more than ten measurements have been assigned individual symbols; all others share a common symbol. Errors are given as in original sources.*

Having an apparent diameter like the full moon, IC 342 would be the most spectacular galaxy on the sky after the Andromeda galaxy, if it was not obscured by the Milky Way. It may be the closest starburst galaxy to us (Roche & Aitken 1985). It is almost fully face-on (Buta & McCall 1999), so that its rotation velocity and, hence, the distance using the Tully–Fisher relation, can not be measured. Galactic extinction towards IC 342 is outrageously high, $A_B = 3.05 \pm 0.25$ mag (McCall 1989), but manageable for Cepheid distance measurements.

In paper IV of this thesis we have measured the distance of IC 342 using Cepheid variable stars. We found a true distance modulus of 27.9 ± 0.2 mag, corresponding to a distance of 3.8 ± 0.4 Mpc. The distance agrees with the Saha et al. (2002) Cepheid distance modulus of 27.58 ± 0.18 within error limits. This distance is clearly large enough for IC 342 to have played no significant rôle in Local Group dynamics.

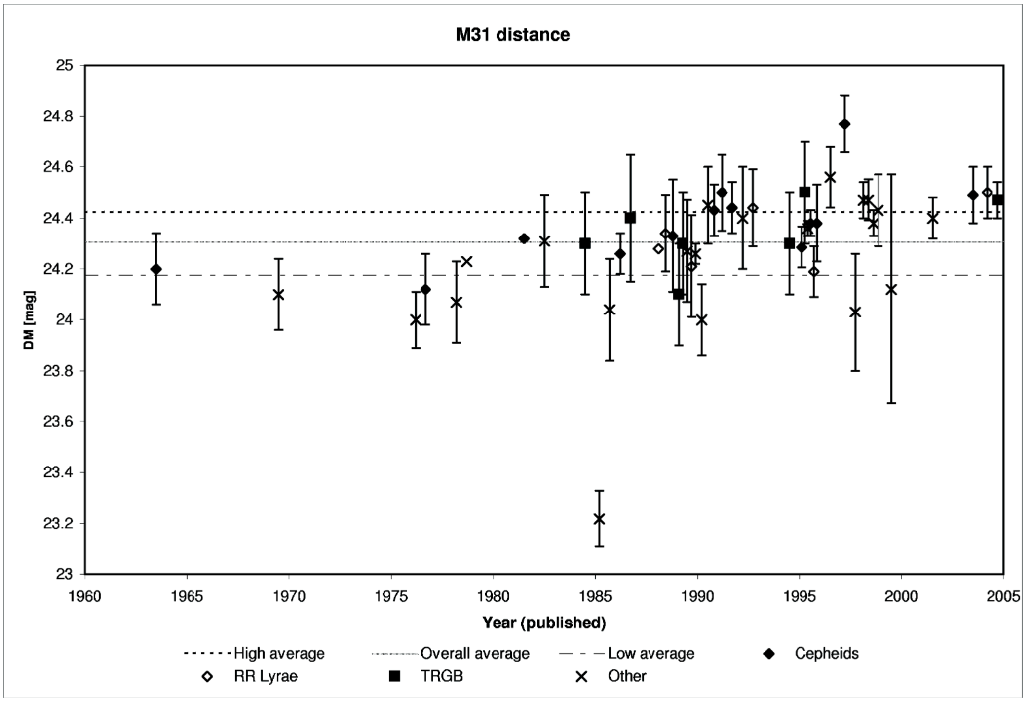

Figure 4.2: *Distances of the Andromeda Galaxy from table B.1 in appendix B. Overall there are 47 distance measurements, of which 45; all within two sigma of the overall average; have been used to calculate the depicted "overall average" distance modulus of 24.31 mag. The clear distinction to high and low distance scale has been acknowledged by separate average values for the 24 distances above and 21 distances below the overall average. All distance measuring methods with more than six measurements have been assigned individual symbols; all others share a common symbol. Errors are given as in original sources.*

4.4 Other distances

Regarding the motivation behind this thesis work, it is simply impossible to measure all Extended Local Group galaxy distances by any one person or group. Measurements by other scientists must be used to build a coherent image of the distribution of the Extended Local Group galaxies. Distances are, however, measured by many different methods with varying zero-points and other effects affecting the results. Very few distances are comparable to each other as such and some level of interpretation must be applied when adopting them into use.

Even the best distance measurement methods have uncertainties in the best observing conditions. Often additional uncertainties are introduced by the quality of instrumentation used for observations, weather and location of the observing facilities and

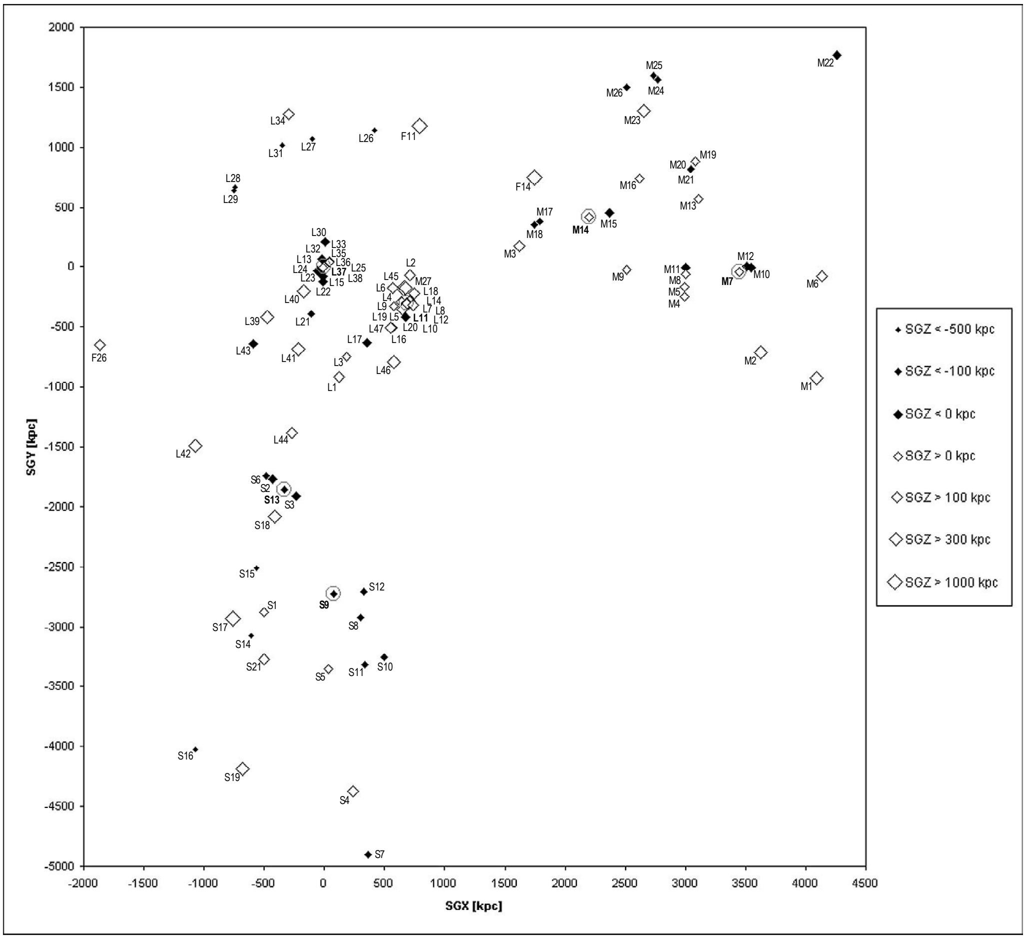

Figure 4.3: *Extended Local Group galaxies on the supergalactic plane; i.e. the SGX-SGY plane seen from the direction of positive SGZ axis. Identification of galaxies is given in table 4.1. Milky Way, Andromeda Galaxy, IC 342, Maffei 1, NGC 300 and NGC 253 have been indicated with an additional circle and boldface identification. The position of galaxies relative to the observed plane is indicated with sizes and shading of symbols as shown in the figure insert.*

surroundings of the target galaxies. In comparison with many targets further away the Extended Local Group galaxies have the advantage of statistics. Most galaxies, especially the closest and largest ones have several tens of distance measurements from many teams of scientists and are obtained with several different distance measuring methods. Such statistics can reveal us much not only about distances to these galaxies but also about distance measuring methods themselves.

Earlier summaries of obtained distances have been published by de Vaucouleurs (1993) and van den Bergh (1994, 1999). A division to long and short extragalactic dis-

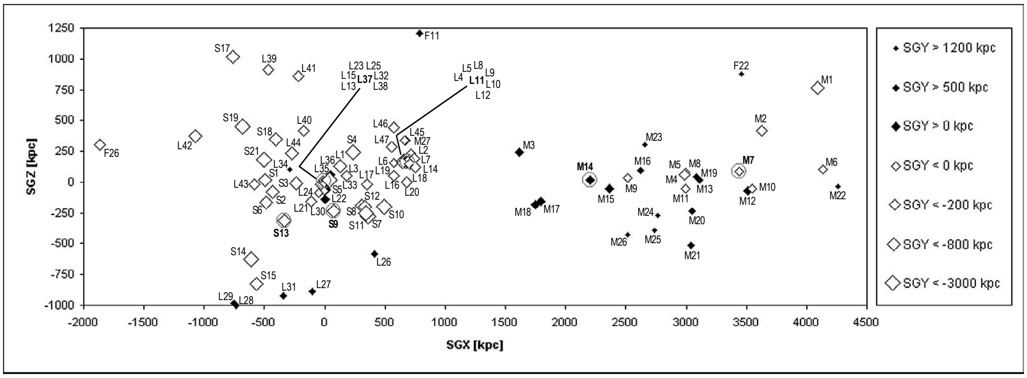

Figure 4.4: *Extended Local Group galaxies perpendicular to the supergalactic plane; i.e. the SXG-SGZ plane seen from the direction of negative SGY axis. For other details see Fig. 4.3 caption.*

TABLE 4.1: IDENTIFICATION OF GALAXIES FOR FIGS 4.3 AND 4.4

ID	Galaxy	ID	Galaxy	ID	Galaxy	ID	Galaxy
L1	WLM	L32	Sextans Dwarf Spheroidal	*F16*	*IC 5026*	M21	UGCA 105
L2	IC 10	L33	Leo II	*F17*	*Capricorn Dwarf*	M22	KKH 34
L3	Cetus Dwarf	L34	GR 8	*F18*	*Anon 2259+12*	M23	KKH 37
L4	NGC 147	L35	Ursa Minor Dwarf	*F19*	*ESO 347-008*	M24	NGC 2366
L5	And III	L36	Draco Dwarf	*F20*	*UGC 3974*	M25	DDO 44
L6	NGC 185	**L37**	**Milky Way**	*F21*	*NGC 2915*	M26	NGC 2403
L7	NGC 205	L38	Sagittarius Dwarf	F22	UGC 6456	M27	Cassiopeia dSph
L8	And VIII	L39	SagDIG	*F23*	*UGC 7131*	S1	Sculptor Dwarf Irregular
L9	And IV	L40	NGC 6822	*F24*	*IC 3104*	S2	NGC 55
L10	M 32	L41	Aquarius Dwarf	*F25*	*Circinus Galaxy*	S3	ESO 410-G005
L11	**Andromeda Galaxy**	L42	IC 5152	F26	IC 4662	S4	NGC 59
L12	And I	L43	Tucana Dwarf	M1	KKH 5	S5	Scl-dE1 (SC22)
L13	SMC	L44	UKS 2323-326	M2	KKH 6	S6	ESO 294-010
L14	And IX	L45	And VII	M3	Cassiopeia 1	S7	IC 1574
L15	Sculptor Dwarf Spheroidal	L46	Pegasus Dwarf	M4	KKH 11	S8	NGC 247
L16	Pisces Dwarf	L47	Pegasus Dwarf Sph.	M5	KKH 12	**S9**	**NGC 253**
L17	IC 1613	*F1*	*ESO 352-002*	M6	MB1	S10	ESO 540-030
L18	And V	*F2*	*Anon 0106+21*	**M7**	**Maffei 1**	S11	ESO 540-031
L19	And II	*F3*	*Anon 0107+01*	M8	MB2	S12	ESO 540-032
L20	M 33	*F4*	*Phoenix Dwarf Irregular*	M9	Maffei 2	**S13**	**NGC 300**
L21	Phoenix Dwarf	*F5*	*ESO 416-012*	M10	Dwingeloo 2	S14	ESO 295-029
L22	Fornax Dwarf Spheroidal	*F6*	*IC 1947*	M11	MB3	S15	NGC 625
L23	LMC	*F7*	*ESO 056-019*	M12	Dwingeloo 1	S16	ESO 245-005
L24	Carina Dwarf	*F8*	*ESO 318-013*	M13	KK 35	S17	KK 258
L25	Canis Major Dwarf	*F9*	*ESO 269-070*	**M14**	**IC 342**	S18	UGCA 438
L26	Leo A	*F10*	*IC 4247*	M15	UGCA 86	S19	ESO 471-006
L27	Sextans B	F11	KKR 25	M16	Camelopardalis A	*S20*	*ESO 149-003*
L28	NGC 3109	*F12*	*IC 4739*	M17	NGC 1569	S21	NGC 7793
L29	Antlia Dwarf	*F13*	*IC 4789*	M18	UGCA 92		
L30	Leo I	F14	NGC 6789	M19	NGC 1560		
L31	Sextans A	*F15*	*IC 4937*	M20	Camelopardalis B		

Galaxies in italics do not appear on Figs. 4.3 and 4.4. Some galaxies are shown in boldface to facilitate finding them in the figures.

tance scale advocates is described by de Vaucouleurs (1993). The distance measuring methods, calibrations and analyses of the two differ and result in two distinct distance ranges. This can be seen in Fig. 4.2 of the Andromeda Galaxy (M31) distances. While present, the distinction is practically not visible in Fig. 4.1 of the Large Magellanic Cloud (LMC) distance because of the large number of distances covering the intermediate range and error estimates reaching the overall average of the distances. The existence of intermediate distance scale advocates, who combine the best arguments of both sides, is also noted by de Vaucouleurs (1993). The constraining of cosmological parameters (Spergel et al. 2003) and improvements in distance measuring methods and their calibrations may have contributed to the development of the Large Magellanic Cloud distance as can be seen in distances measured during the last few years. This has also been noted by Alves (2004) by a trend of convergence toward a standard value, which he estimates to be 18.50 ± 0.02 mag as a weighted average of fourteen recent distances.

A survey of Extended Local Group galaxy distances has been conducted in the NASA Astrophysics Data System (ADS) with results written in table B.1 in appendix B. The table contains the name of the galaxy, distance and the corresponding error in distance moduli and kiloparsecs, the method used to derive the distance, the year of publication and the reference. All distances for the Large Magellanic Cloud and the Andromeda Galaxy from table B.1 have been plotted in Figs. 4.1 and 4.2.

The abovementioned distance scale discrepancy of the Andromeda Galaxy, which is also present in many other galaxies, makes it difficult to simply calculate an average distance of all obtained ones. In relatively clear cases, such as the Andromeda Galaxy, a recent trend has been adopted as the representative of the most reliable distance. Often there was not enough statistics to find a trend and a simple average of all distances was calculated, excluding most deviant values in some cases. Such an example is shown in Fig. 4.2 of Andromeda Galaxy distances. Issa (1985) found a distance a whole magnitude smaller than the average of all others using size distribution of H II regions. While he notes that even a distance of 651 kpc would mean the H II regions of the Andromeda Galaxy and the Milky Way are strikingly different, his distance has still been omitted from any average calculated for the Adromeda Galaxy in this study. The adopted distances of this work have been listed in table A.1 in appendix A.

Positions and distances of galaxies, from table A.1, have been processed into graphical form in Fig. 4.3, which shows the Extended Local Group galaxies in the supergalactic cartesian coordinate system as seen from positive SGZ axis, and Fig. 4.4, which is the same but seen from positive SGX axis. Identification of galaxies for Figs. 4.3 and 4.4 is given in table 4.1.

CHAPTER 5
Conclusions

The physical basis and direct use of three important distance measuring methods has been presented. The Cepheid variable star method is the current standard method for measuring extragalactic distances – a method all others are calibrated or compared to. Planetary nebula luminosity function method is relatively new but has certain very interesting advantages over most other methods. Surface brightness fluctuation method has been found to be very powerful when measuring distances of low surface-brightness dwarf elliptical galaxies in the local volume. All these methods have been used to measure distances within the Extended Local Group of galaxies.

Dwarf elliptical galaxies have recently been detected in large numbers. As a part of ongoing study to map their distribution among nearby galaxy groups distances to fifteen of them, and one lenticular galaxy, have been measured within a distance range of three to sixteen megaparsecs using the surface brightness fluctuation method. An empirical calibration for the method has been performed and found to improve the previous theoretical calibration from synthetic stellar population models (Paper I). Distances measured using the new empirical calibration have been found to be consistent with existing distances obtained with other methods. Several of the galaxies had, however, no previous distances and our surface brightness fluctuation distances were used to confirm or, in a couple of cases, to refuse their speculated membership in nearby groups (Paper III).

Implications for dwarf galaxy studies may reach further in the fundamentals of cosmology. The current sample is still quite small, but we may already challenge the possibility of dwarf galaxies as a solution for the missing satellite problem for large galaxies (Moore et al. 1999). As their numbers build up we may be able to use dwarf galaxies to trace the smoothness of the Hubble flow within a few megaparsec range and build a theory on how the dark energy operates within the local supercluster (Chernin et al. 2004).

A distance to a major Sculptor group galaxy, the dusty starburst spiral galaxy NGC 253, has been measured using the planetary nebula luminosity function method. No Cepheid distance exists for this galaxy, but the few distances obtained with other methods agree well with our distance and we are able to place this galaxy at a distance of 3.6 ± 0.2 megaparsecs. The high amount of dust in NGC 253 may have proven an impossible obstacle for acquiring accurate distances with certain other methods. An analysis on the effects of dust on the planetary nebula luminosity function has shown that the method is very insensitive to dust. (Paper II)

The Sculptor group of galaxies has been suggested having a common dynamical history with the Local Group. Our distance to NGC 253, together with its radial velocity relative to the Local Group barycentre, is consistent with the position of the galaxy in the Hubble flow. Therefore it is no longer reasonable to include the NGC 253 subgroup in studies of the Local Group dynamics. The Sculptor group has, however, several subgroups of which one is concentrated around a much closer NGC 300. Relevance of this subgroup to the Local Group dynamics remains to be determined (Paper II).

Another major starburst spiral galaxy nearby is IC 342, which is one of the massive members of IC 342 / Maffei group of galaxies – located inconveniently behind the zone-of-avoidance. We have used the Cepheid variable star method to establish a distance of 3.8 ± 0.4 megaparsecs to this galaxy. The distance is within error limits to a previous Cepheid distance of 3.4 ± 0.2 megaparsecs. Due to the galactic dust, IC 342 is plagued with an extremely high amount of reddening. Any error in determining the reddening or adopting a correct value for distance measurements will affect the distance considerably.

The IC 342 / Maffei group of galaxies is the closest group to the Local Group and is the primary target for a search of Local Group interlopers. The group is quite large and it may be regarded impossible the whole group has had dynamical interaction with any part of the Local Group. The possibility that some galaxies in that direction may have originated from or passed through the Local Group should be kept in mind.

A vigorous effort has been made to collate the best distances to all Extended Local Group galaxies. The results, from literature, have been collected and presented in Appendix B. Adopted average distances and other data on the galaxies is presented in Appendix A.

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This research has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, Caltech, under contract with the National Aeronautics and Space Administration.

APPENDIX A
Extended Local Group galaxies

The following table presents all known and suspected Extended Local Group galaxies with their celestial positions in equatorial system (J2000.0), galactic coordinates, mean distances as calculated in Appendix B, heliocentric, galactocentric and Local Group barycentric radial velocities, extinction, and classification. Galaxies have been divided into five groups in the table: **Local Group** denotes galaxies, which are currently believed to be certain members of the Local Group; **Local Group?** denotes galaxies with past or present speculations on their membership in the Local Group; **Field galaxies?** denotes galaxies, which are very nearby field galaxies or galaxies with that status but may ultimately be found to be part of the Local Group; **IC 342 / Maffei group** denotes all currently known or speculated IC 342 / Maffei group galaxies; and **Sculptor group** denotes all currently known or speculated Sculptor group galaxies.

TABLE A.1

Galaxy	α (J2000.0)			δ (J2000.0)			l	b	$(m-M)_0$	D	$v_{r\,(\odot)}$	$v_{r\,(GSR)}$	$v_{r\,(LG)}$	A_B	Type
	[h]	[m]	[s]	[d]	[m]	[s]	[deg]	[deg]	[mag]	[kpc]	[km s^{-1}]	[km s^{-1}]	[km s^{-1}]	[mag]	
Local Group															
WLM	0	01	58.1	-15	27	39	75.86	-73.62	24.85 ± 0.08	935 ± 37	-116	-59	-11	0.160	IB(s)m
IC 10	0	20	17.3	59	18	14	118.96	-3.33	24.38 ± 0.63	753 ±255	-348	-150	-89	6.588	dIrr IV/BCD
Cetus Dwarf	0	26	11.0	-11	02	40	101.45	-72.86	24.43 ± 0.04	770 ± 14	?	?	?	0.124	dSph
NGC 147	0	33	12.1	48	30	32	119.82	-14.25	24.25 ± 0.22	708 ± 76	-193	-4	57	0.747	dSph/dE5
And III	0	35	33.8	36	29	52	119.37	-26.26	24.39 ± 0.02	755 ± 7	-351	-177	-116	0.244	dSph
NGC 185	0	38	58.0	48	20	15	120.79	-14.48	23.95 ± 0.10	617 ± 29	-202	-15	46	0.787	dSph/dE3
NGC 205	0	40	22.1	41	41	07	120.71	-21.14	24.59 ± 0.11	826 ± 44	-241	-62	-1	0.268	E5 pec
And VIII	0	42	06.0	40	37	00	121.02	-22.22	? ± ?	? ± ?	?	?	?	0.268	?
And IV	0	42	32.3	40	34	19	121.10	-22.27	24.29 ± 0.36	721 ±130	256	433	494	0.268	dIrr
M 32	0	42	41.8	40	51	55	121.15	-21.98	24.43 ± 0.18	767 ± 65	-200	-23	38	0.268	cE2
Andromeda Galaxy	0	42	44.3	41	16	09	121.17	-21.57	24.42 ± 0.07	767 ± 24	-300	-122	-61	0.268	SA(s)b
And I	0	45	39.8	38	02	28	121.68	-24.82	24.42 ± 0.08	767 ± 30	-368	-196	-135	0.234	E3 pec?
SMC	0	52	44.8	-72	49	43	302.79	-44.30	18.94 ± 0.27	61 ± 8	158	17	-44	0.160	SB(s)m pec
And IX [1]	0	52	52.9	43	11	54	123.21	-19.67	24.45 ± 0.04	776 ± 15	?	?	?	0.260	dSph
Sculptor dSph.	1	00	09.3	-33	42	33	287.53	-83.16	19.59 ± 0.17	83 ± 7	110	77	16	0.077	E?
Pisces Dwarf	1	03	55.0	21	53	06	126.76	-40.89	24.42 ± 0.37	767 ±144	-287	-155	-94	0.177	dIrr/dSph
IC 1613	1	04	47.8	2	07	04	129.74	-60.58	24.28 ± 0.09	719 ± 30	-234	-155	-93	0.108	IB(s)m
And V	1	10	17.1	47	37	41	126.22	-15.12	24.50 ± 0.08	793 ± 29	-403	-229	-168	0.537	dSph
And II	1	16	29.8	33	25	09	128.92	-29.16	24.11 ± 0.24	665 ± 79	-188	-39	22	0.269	dSph
M 33	1	33	50.9	30	39	36	133.61	-31.33	24.50 ± 0.28	794 ±108	-179	-44	16	0.181	SA(s)cd

[1] The extinction of Andromeda IX is for A_V from Zucker et al. 2004, *ApJ*, **612**, 121L

TABLE A.1 CONTINUED

Galaxy	α (J2000.0)			δ (J2000.0)			l	b	$(m–M)_0$	D	$v_{r\,(\odot)}$	$v_{r\,(GSR)}$	$v_{r\,(LG)}$	A_B	Type
	[h]	[m]	[s]	[d]	[m]	[s]	[deg]	[deg]	[mag]	[kpc]	[km s^{-1}]	[km s^{-1}]	[km s^{-1}]	[mag]	
Local Group															
Phoenix Dwarf	1	51	06.3	-44	26	41	272.16	-68.95	23.21 ± 0.19	439 ± 40	56	-34	-86	0.067	IAm
Fornax dSph.	2	39	59.3	-34	26	57	237.10	-65.65	20.69 ± 0.07	137 ± 5	53	-36	-50	0.087	dE0
LMC	5	23	34.5	-69	45	22	280.46	-32.89	18.44 ± 0.10	49 ± 2	278	84	22	0.324	SB(s)m
Carina Dwarf	6	41	36.7	-50	57	58	260.11	-22.22	20.11 ± 0.35	105 ± 18	229	13	-35	0.271	E3
Canis Major Dwarf	7	10	34.9	-27	35	34	240.00	-8.00	15.71 ± 0.44	14 ± 3	?	?	?	?	dSph?
Leo A	9	59	26.4	30	44	47	196.90	52.42	25.65 ± 1.23	1349 ±1026	24	-17	-1	0.089	IBm
Sextans B	10	00	00.1	5	19	56	233.20	43.78	25.72 ± 0.22	1390 ±146	300	167	140	0.137	ImIV-V
NGC 3109	10	03	06.9	-26	09	34	262.10	23.07	25.75 ± 0.34	1411 ±238	403	193	144	0.288	SB(s)m
Antlia Dwarf	10	04	03.9	-27	19	55	263.10	22.31	25.72 ± 0.37	1395 ±259	362	151	101	0.342	dE3.5
Leo I	10	08	27.4	12	18	27	225.98	49.11	21.93 ± 0.25	243 ± 29	285	177	104	0.156	E, dSph
Sextans A	10	11	00.8	-4	41	34	246.15	39.88	25.75 ± 0.19	1410 ±131	324	163	125	0.188	IBm
Sextans dSph.	10	13	02.9	-1	36	53	243.50	42.27	19.73 ± 0.12	88 ± 5	224	72	16	0.215	dSph
Leo II	11	13	29.2	22	09	17	220.16	67.23	21.67 ± 0.11	216 ± 11	-87	-141	-93	0.072	E0 pec
GR 8	12	58	40.4	14	13	03	310.74	76.98	25.58 ± 1.01	1308 ±775	214	183	122	0.113	ImV
Ursa Minor Dwarf	15	09	08.5	67	13	21	104.96	44.80	19.30 ± 0.19	72 ± 7	-247	-85	-21	0.137	E
Draco Dwarf	17	20	12.4	57	54	55	86.37	34.72	19.71 ± 0.23	88 ± 10	-292	-97	-20	0.118	E pec
Milky Way	17	45	36.0	-28	56	00	0.00	0.00	14.57 ± 0.06	8 ± 0.2	—	0	?	—	
Sagittarius Dwarf	18	55	19.5	-30	32	43	5.57	-14.17	16.90 ± 0.19	24 ± 2	140	169	55	0.661	dSph(t)
SagDIG	19	29	59.0	-17	40	41	21.05	-16.29	25.22 ± 0.13	1107 ± 69	-77	9	-2	0.522	IB(s)m
NGC 6822	19	44	56.6	-14	47	21	25.35	-18.39	23.47 ± 0.11	493 ± 26	-57	43	29	1.020	IB(s)m
Aquarius Dwarf	20	46	51.8	-12	50	53	34.05	-31.34	25.25 ± 1.25	1120 ±873	-137	-23	-19	0.221	IB(s)m
IC 5152	22	02	41.5	-51	17	47	343.92	-50.19	26.37 ± 0.30	1875 ±282	124	83	38	0.106	IA(s)m
Tucana Dwarf	22	41	49.0	-64	25	12	322.91	-47.37	24.70 ± 0.02	872 ± 6	130	35	-22	0.137	dE4
UKS 2323-326	23	26	27.5	-32	23	20	11.87	-70.86	25.78 ± 1.15	1432 ±995	62	74	52	0.064	IB(s)m pec:
And VII	23	26	31.0	50	41	31	109.46	-9.95	24.41 ± 0.10	762 ± 36	-307	-96	-34	0.838	Sph?
Pegasus Dwarf	23	28	36.2	14	44	35	94.77	-43.55	25.16 ± 0.63	1078 ±364	-183	-21	35	0.284	dIrr/dSph
Pegasus dSph.	23	51	46.3	24	34	57	106.04	-36.33	24.52 ± 0.07	801 ± 27	-354	-181	-117	0.276	Sph?
Local Group?															
ESO 352-002	1	04	30.4	-33	39	16	280.41	-82.89	? ± ?	? ± ?	10011	9976	?	0.118	Sc
Anon 0106+21	1	06	18.0	21	39	00	127.51	-41.09	? ± ?	? ± ?	?	?	?	?	?
Anon 0107+01	1	07	24.0	1	52	00	131.11	-60.75	? ± ?	? ± ?	?	?	?	?	?
ESO 416-012	2	43	38.2	-31	56	38	230.90	-65.20	? ± ?	? ± ?	4983	4899	?	0.078	SAB(rs)c:
IC 1947	3	30	32.8	-50	20	19	261.42	-51.96	? ± ?	? ± ?	11545	11397	?	0.057	S
ESO 056-019	4	53	18.4	-70	35	55	282.23	-35.16	? ± ?	? ± ?	273	85	?	0.324	LMC emiss.reg.?
ESO 318-013	10	47	41.9	-38	51	15	278.04	17.97	? ± ?	? ± ?	17	-198	?	0.326	SB(s)d: sp
ESO 269-070	13	13	28.2	-43	22	59	307.17	19.31	? ± ?	? ± ?	22300	22133	?	0.570	SAB(r)0^+?
IC 4247	13	26	44.4	-30	21	45	311.90	31.89	? ± ?	? ± ?	274	136	?	0.269	S?
KKR 25	16	13	47.6	54	22	16	83.88	44.41	26.35 ± 0.14	1862 ±124	-139	31	80	0.036	Ir
IC 4739	18	40	51.0	-61	54	06	333.55	-22.51	? ± ?	? ± ?	4430	4339	?	0.500	S?
IC 4789	18	56	18.5	-68	34	02	326.82	-25.55	? ± ?	? ± ?	4234	4123	?	0.250	SA(s)c:
NGC 6789	19	16	41.1	63	58	24	94.97	21.52	27.02 ± 0.68	2536 ±925	-141	76	131	0.302	Im
IC 4937	20	05	17.6	-56	15	22	341.54	-32.39	? ± ?	? ± ?	4758	4699	?	0.234	Sb
IC 5026	20	48	28.0	-78	04	09	315.27	-32.42	? ± ?	? ± ?	2748	2612	?	0.594	Sc
Capricorn Dwarf	21	46	38.9	-21	15	10	30.51	-47.68	? ± ?	? ± ?	61	140	?	0.156	Star cluster?
Anon 2259+12	23	01	36.0	12	44	00	85.65	-42.05	? ± ?	? ± ?	?	?	?	?	?
ESO 347-008	23	20	49.1	-41	43	51	348.85	-66.41	? ± ?	? ± ?	1622	1601	?	0.081	SAB(s)m

TABLE A.1 CONTINUED

Galaxy	α (J2000.0)			δ (J2000.0)			l	b	$(m–M)_0$	D	$v_{r\,(\odot)}$	$v_{r\,(GSR)}$	$v_{r\,(LG)}$	A_B	Type
	[h]	[m]	[s]	[d]	[m]	[s]	[deg]	[deg]	[mag]	[kpc]	[km s^{-1}]	[km s^{-1}]	[km s^{-1}]	[mag]	
Field galaxies?															
UGC 3974	7	41	55.4	16	48	09	203.10	18.54	28.57 ± 0.15	5176 ±370	272	180	188	0.145	IB(s)m:
NGC 2915	9	26	11.5	-76	37	35	291.96	-18.36	28.26 ± 0.52	4479 ±1204	468	265	204	1.185	I0
UGC 6456	11	27	59.9	78	59	39	127.83	37.33	28.22 ± 0.03	4412 ± 63	-103	43	103	0.155	Pec
UGC 7131	12	09	11.8	30	54	24	188.17	80.03	30.80 ± ?	14454 ± ?	253	253	276	0.096	Sdm:
IC 3104	12	18	46.0	-79	43	34	301.41	-16.95	26.78 ± 0.18	2270 ±196	430	243	182	1.701	IB(s)m:
Circinus Galaxy	14	13	9.9	-65	20	21	311.32	-3.81	27.24 ± ?	2800 ± ?	449	281	220	6.276	SA(s)b:
IC 4662	17	47	6.4	-64	38	25	328.55	-17.85	26.51 ± 0.21	2000 ±203	308	198	143	0.303	IBm
IC 342 / Maffei Group															
KKH 5	1	07	32.5	51	26	26	125.49	-11.35	28.15 ± 0.17	4266 ±347	61	240	301	1.218	Ir?
KKH 6	1	34	51.5	52	05	30	129.68	-10.21	27.85 ± ?	3720 ± ?	53	222	282	1.515	Ir
Cassiopeia 1	2	06	02.8	68	59	59	129.56	7.09	26.08 ± 1.55	1645 ±1710	35	208	268	4.399	dIrr
KKH 11	2	24	34.2	56	00	43	135.74	-4.53	27.39 ± ?	3000 ± ?	310	464	523	2.13	dE/N
KKH 12	2	27	26.9	57	29	16	135.58	-3.01	27.39 ± ?	3000 ± ?	70	225	284	3.438	Ir
MB1	2	35	26.5	59	22	43	135.83	-0.86	28.08 ± 0.99	4135 ±2375	190	345	404	4.219	SAB(s)d?
Maffei 1	2	36	35.4	59	39	19	135.86	-0.55	27.69 ± 0.66	3446 ±1230	13	168	227	5.046	S0- pec:
MB2	2	36	59.8	59	14	14	136.07	-0.91	? ± ?	? ± ?	?	?	?	4.027	dIrr
Maffei 2	2	41	55.1	59	36	15	136.50	-0.33	27.00 ± 0.33	2515 ±412	-17	136	195	10.013	SAB(rs)bc:
Dwingeloo 2	2	54	08.5	59	00	19	138.16	-0.19	27.75 ± 0.52	3550 ±953	94	242	300	5.127	Irr?
MB3	2	55	42.7	58	51	37	138.41	-0.23	27.39 ± ?	3000 ± ?	59	206	264	5.638	dSph
Dwingeloo 1	2	56	51.9	58	54	42	138.52	-0.11	27.73 ± 0.69	3510 ±1322	110	257	315	6.345	SB(s)cd
KK 35 [2]	3	45	12.6	67	51	50	138.20	10.31	27.50 ± 0.22	3162 ±337	-66	81	139	2.34	?
IC 342	3	46	48.5	68	05	46	138.17	10.58	26.75 ± 0.70	2237 ±853	31	178	236	2.407	SAB(rd)cd
UGCA 86	3	59	50.5	67	08	37	139.76	10.65	26.91 ± 0.30	2410 ±353	67	209	266	4.061	Irr?
Camelopardalis A [1]	4	19	26.7	72	41	27	137.03	15.80	27.18 ± 1.12	2723 ±1847	-127	21	80	0.93	Irr
NGC 1569	4	30	49.0	64	50	53	143.68	11.24	26.32 ± 0.18	1837 ±162	-104	25	81	3.020	IBm Sbrst
UGCA 92	4	32	04.9	63	36	49	144.71	10.52	26.26 ± 0.02	1789 ± 15	-99	27	83	3.419	Irr?
NGC 1560	4	32	49.1	71	52	59	138.36	16.02	27.53 ± 0.23	3206 ±352	-36	108	166	0.812	SA(s)d
Camelopardalis B	4	53	07.1	67	05	57	143.38	14.42	27.50 ± 0.17	3166 ±251	77	206	262	0.936	Irr
UGCA 105	5	14	15.3	62	34	48	148.52	13.66	27.52 ± 0.04	3184 ± 52	111	223	277	1.351	Irr?
KKH 34	5	59	40.4	73	25	40	140.42	22.35	28.32 ± 0.17	4613 ±376	110	243	301	1.076	Ir
KKH 37	6	47	45.8	80	07	26	133.98	26.54	27.36 ± ?	2970 ± ?	-148	-1	59	0.330	S/Irr
NGC 2366	7	28	54.6	69	12	57	146.42	28.54	27.52 ± ?	3190 ± ?	100	209	264	0.157	IB(s)m
DDO 44	7	34	11.4	66	53	10	149.09	28.96	27.52 ± ?	3190 ± ?	?	?	?	0.178	Irr:
NGC 2403	7	36	51.4	65	36	9	150.57	29.19	27.35 ± 0.35	2957 ±514	131	227	280	0.172	SAB(s)cd
Cassiopeia dSph [2]	23	26	31.8	50	40	32	109.46	-9.96	24.45 ± 0.07	776 ± 26	-307	-96	-34	0.85	dSph

[1] All data on Camelopardalis A has been adopted from Karachentsev et al. 1999, *MNRAS*, **307**, 37L

[2] All data on KK 35 and Cassiopeia dSph have been adopted from Karachentsev et al. 2003, *A&A*, **408**, 111

TABLE A.1 CONTINUED

Galaxy	α (J2000.0)			δ (J2000.0)			l	b	$(m-M)_0$	D	$v_{r(\odot)}$	$v_{r(GSR)}$	$v_{r(LG)}$	A_B	Type
	[h]	[m]	[s]	[d]	[m]	[s]	[deg]	[deg]	[mag]	[kpc]	[km s^{-1}]	[km s^{-1}]	[km s^{-1}]	[mag]	
Sculptor group															
Sculptor dIrr.	0	08	13.3	-34	34	42	351.48	-78.12	27.33 ± 0.52	2919 ±793	207	195	155	0.054	IBm
NGC 55	0	14	53.6	-39	11	48	332.88	-75.73	26.30 ± 0.66	1822 ±643	129	98	46	0.057	SB(s)m: sp
ESO 410-G005	0	15	31.4	-32	10	47	357.85	-80.71	26.42 ± 0.20	1923 ±186	?	?	?	0.059	E3:
NGC 59	0	15	25.1	-21	26	40	65.71	-80.02	28.21 ± ?	4385 ± ?	382	412	446	0.088	SA(rs)0-:
Scl-dE1 (SC22)	0	23	51.7	-24	42	18	52.74	-83.34	27.63 ± 0.70	3350 ±1274	?	?	?	0.063	dE
ESO 294-010	0	26	33.4	-41	51	19	320.41	-74.42	26.30 ± 0.18	1816 ±154	117	72	15	0.024	dS0/Im
IC 1574	0	43	03.8	-22	14	49	101.20	-84.76	28.46 ± 0.26	4920 ±626	361	375	432	0.065	IB(s)m
NGC 247	0	47	08.5	-20	45	37	113.95	-83.56	27.35 ± 0.64	2949 ±1010	160	176	237	0.078	SAB(s)d
NGC 253	0	47	33.1	-25	17	18	97.38	-87.96	27.19 ± 0.55	2741 ±788	241	242	298	0.081	SAB(s)c Sbrst
ESO 540-030	0	49	20.9	-18	04	32	119.78	-80.93	27.59 ± 0.10	3296 ±154	?	?	?	0.100	IABm
ESO 540-031	0	49	49.2	-21	00	54	119.39	-83.88	27.62 ± 0.16	3342 ±256	295	309	370	0.073	IB(s)m:
ESO 540-032	0	50	24.3	-19	54	24	121.00	-82.77	27.19 ± 0.54	2739 ±772	?	?	?	0.088	IAB(s)m pec:
NGC 300	0	54	53.5	-37	41	04	299.20	-79.42	26.41 ± 0.37	1910 ±356	144	101	40	0.055	SA(s)d
ESO 295-029	1	02	32.8	-39	04	14	292.64	-77.84	? ± ?	? ± ?	6086	6035	?	0.061	(R':)SA(r?)c?
NGC 625	1	35	04.7	-41	26	13	273.67	-73.12	27.16 ± ?	2700 ± ?	405	331	276	0.07	
ESO 245-005	1	45	03.3	-43	35	56	273.08	-70.29	28.23 ± 0.23	4426 ±495	394	309	255	0.07	
KK 258	22	40	43.7	-30	47	55	17.73	-61.28	? ± ?	? ± ?	?	?	?	0.06	
UGCA 438	23	26	27.5	-32	23	20	11.87	-70.86	26.67 ± 0.11	2153 ±108	62	74	53	0.064	IB(s)m pec:
ESO 471-006	23	43	45.5	-31	57	24	10.70	-74.53	28.15 ± 0.27	4266 ±565	267	274	252	0.072	SB(s)m: sp
ESO 149-003	23	52	02.2	-52	34	38	322.46	-62.24	29.03 ± ?	6400 ± ?	577	508	451	0.06	
NGC 7793	23	57	49.8	-32	35	28	4.51	-77.17	27.60 ± 0.38	3319 ±628	230	229	201	0.084	SA(s)d

The equatorial coordinates, heliocentric radial velocities and galaxy classifications have been adopted from the NASA/IPAC Extragalactic Database (NED). Galactic coordinates have been calculated using Coordinate Conversions (CooC). Extinction, A_B, is the value from Schlegel et al. (1998[1]) as given in the NED.

The Earth, as part of the solar system, rotates around the centre of our galaxy, the Milky Way, at a distance of ≈8 kpc (e.g. Eisenhauer et al. 2003[1]) and with a velocity of ≈235 km s^{-1} (e.g. Carlberg & Innanen 1987[1]). It is located only ≈16 parsecs above the galactic plane (Hammersley et al. 1995[1]). The movement of the Earth in the Milky Way affects all radial velocity measurements. Heliocentric radial velocities have been converted to galactocentric velocities using equation provided by de Vaucouleurs et al. (1991[1]) and further to Local Group barycentric velocities, i.e. velocities relative to the Local Group centre of mass, by

$$v_{r(LG)} = v_{r(GSR)} \cos\left(\arcsin\left(\frac{r_0 \sin j}{\sqrt{r_0^2 + r_1^2 - 2 r_0 r_1 \cos j}} \right) \right) + r_0 \cos j \qquad \text{(B.1)}$$

where r_0 is the distance from the Milky Way to the assumed Local Group centre of mass exactly half way between the Milky Way and the Andromeda Galaxy, r_1 is the distance from the Milky Way to the galaxy, j is the angular distance on the sky from the galaxy to the Andromeda Galaxy and $v_{\mathrm{r(GSR)}}$ is the radial velocity of the galaxy relative to the Milky Way.

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[1] For references see Bibliography, pp. 41-47

APPENDIX B
Comparison of distances

The following table presents an extensive sample of distances to Extended Local Group galaxies from literature gathered using the NASA Astrophysics Data System (ADS). The table contains a major share of all published distances, but is not complete because sometimes distance measurements are not mentioned in the paper abstract. The table lists the name of the galaxy; in the same order as in table A.1 (appendix A), i.e. each category in the order of increasing right ascension; distance modulus and corresponding distance in kiloparsecs with errors, the method the distance was obtained with, and literary reference.

TABLE B.1

Galaxy	DM [mag]	error [mag]	Distance [kpc]	error(+) [kpc]	error(–) [kpc]	Method	Year	Author
Local Group								
WLM	26.23	± 0.14	1762.0	117.3	-110.0	supergiants	1977	Ables
	26.06	± 0.39	1629.3	320.5	-267.9	BS / H II	1978	de Vaucouleurs
	24.93		968.3			Cepheids	1985	Sandage
	24.89	± 0.15	950.6	68.0	-63.4	Cepheids	1991	Madore
	24.75	± 0.10	891.3	42.0	-40.1	TRGB	1997	Minuiti
	24.73	± 0.07	883.1	28.9	-28.0	CMD	1999	Hodge et al.
	24.95	± 0.13	977.2	60.3	-56.8	CMD	2000	Rejkuba et al.
	24.88	± 0.09	946.2	40.0	-38.4	CMD	2000	Dolphin
	24.85	± 0.08	933.3	35.0	-33.8	TRGB	2004	McConnachie et al.
IC 10	25.48		1250.0			H II regions	1964	de Vaucouleurs
	25.48		1250.0			H II regions	1964	de Vaucouleurs
	27.36		2964.8			H II regions	1974 b	Sandage & Tammann
	26.51		2000.0			H II regions	1978	de Vaucouleurs
	26.28		1800.0			PN	1981	Jacoby
	26.51		2000.0			Tully-Fisher	1984	Bottinelli
	26.71		2200.0			PN	1989	Ciardullo
	25.08	± 0.18	1037.5	89.7	-82.5	brightest stars	1993	Karachentsev
	24.90	± 0.37	955.0	177.4	-149.6	Wolf-Rayet stars	1995	Massey
	24.59	± 0.30	827.9	122.7	-106.8	Cepheids	1996	Saha
	24.57	± 0.21	820.4	83.3	-75.6	Cepheids	1996	Wilson
	24.17	± 0.14	682.3	45.4	-42.6	SBF	1998	Jensen
	24.10		660.0			Cepheids	1999	Sakai
	23.49		500.0			TRGB	1999	Sakai
	23.82		580.0			VR1	1999	Tikhonov
	23.86	± 0.12	591.6	33.6	-31.8	supergiants	2000	Borissova et al.
	24.96		980.0			TRGB	2001	Hunter
	24.35	± 0.11	741.3	38.5	-36.6	carbon stars	2004	Demers et al.
Cetus Dwarf	24.45	± 0.15	776.2	55.5	-51.8	TRGB	1999	Whiting et al.
	24.46	± 0.14	779.8	51.9	-48.7	TRGB	2002	Sarajedini et al.
	24.39	± 0.07	755.1	24.7	-24.0	TRGB	2004	McConnachie et al.
NGC 147	23.92	± 0.25	608.1	74.2	-66.1	RR lyrae	1990	Saha
	24.30	± 0.36	724.4	130.6	-110.7	TRGB	1994	Davidge
	24.44	± 0.16	772.7	59.1	-54.9	SBF	2001	Tonry et al.
	24.44		772.7			TRGB	2003	Nowotny et al.
	24.15	± 0.09	676.1	28.6	-27.4	TRGB	2004	McConnachie et al.

TABLE B.1 CONTINUED

Galaxy	DM [mag]		error [mag]	Distance [kpc]	error(+) [kpc]	error(–) [kpc]	Method	Year	Author
Local Group									
And III	24.41	±	0.08	762.1	28.6	-27.6	SBF	1992	Caldwell
	24.40	±	0.20	758.6	73.2	-66.7	CMD	1993	Armandroff
	24.38	±	0.06	751.6	21.1	-20.5	HB	2002	Da Costa et al.
	24.37	±	0.07	748.2	24.5	-23.7	TRGB	2004	McConnachie et al.
NGC 185	23.79	±	0.25	572.8	69.9	-62.3	RR lyrae	1990	Saha
	23.95	±	0.10	616.6	29.1	-27.8	TRGB	1998	Martinez-Delgado
	24.02	±	0.16	636.8	48.7	-45.2	SBF	2001	Tonry et al.
	24.04			642.7			TRGB	2003	Nowotny et al.
	23.95	±	0.09	616.6	26.1	-25.0	TRGB	2004	McConnachie et al.
NGC 205	24.43	±	0.15	769.1	55.0	-51.3	CMD	1984	Mould
	24.68	±	0.35	863.0	150.9	-128.5	PNLF	1989	Ciardullo et al.
	24.65	±	0.25	851.1	103.9	-92.6	RR lyrae	1992	Saha
	24.58	±	0.07	824.1	27.0	-26.1	TRGB	2004	McConnachie et al.
And VIII	–		–	–	–	–	–	–	–
And IV	24.29	±	0.36	721.1	130.0	-110.2		1995	Richer
M 32	24.30	±	0.20	724.4	69.9	-63.7	TRGB	1989	Freedman
	24.55	±	0.08	812.8	30.5	-29.4	SBF	2001	Tonry et al.
Andromeda Galaxy	24.20	±	0.14	691.8	46.1	-43.2	Cepheids	1963	Baade
	24.10	±	0.14	660.7	44.0	-41.3	several	1969	van den Bergh
	24.00	±	0.11	631.0	32.8	-31.2	several	1976	van den Bergh
	24.12	±	0.14	666.8	44.4	-41.6	Cepheids	1976	Sandage
	24.07	±	0.16	651.6	49.8	-46.3	several	1978	de Vaucouleurs
	24.23			701.5			luminosity index	1978	de Vaucouleurs
	24.32			731.1			Cepheids	1981	Sandage
	24.31	±	0.18	727.7	63.0	63.0	dark clouds	1982	Osman et al.
	24.30	±	0.20	724.4	69.9	-63.7	TRGB	1984	Mould
	23.22	±	0.11	440.1	22.9	-21.7	H II regions	1985	Issa
	24.04	±	0.20	642.7	62.0	-56.5	novae	1985	Cohen
	24.26	±	0.08	711.2	26.7	-25.7	Cepheids	1986	Welch
	24.40	±	0.25	758.6	92.6	-82.5	TRGB	1986	Mould
	24.28			717.8			RR Lyrae	1988	Pritchet
	24.34	±	0.15	737.9	52.8	-49.3	RR Lyrae	1988	Pritchet
	24.33	±	0.22	734.5	78.3	-70.8	Cepheids	1988	Sandage
	24.10	±	0.20	660.7	63.7	-58.1	TRGB	1989	Freedman
	24.30	±	0.20	724.4	69.9	-63.7	TRGB	1989	Freedman
	24.27	±	0.20	714.5	68.9	-62.9	novae	1989	Capaccioli
	24.21	±	0.20	695.0	67.1	-61.2	RR Lyrae	1989	Clementini
	24.26	±	0.04	711.2	13.2	-13.0	PNLF	1989	Ciardullo et al.
	24.00	±	0.14	631.0	42.0	-39.4	novae	1990	de Vaucouleurs
	24.45	±	0.15	776.2	55.5	-51.8	AGB fitting	1990	Richer
	24.43	±	0.10	769.1	36.2	-34.6	Cepheids	1990	Freedman
	24.50	±	0.15	794.3	56.8	-53.0	Cepheids	1991	Metcalfe & Shanks
	24.44	±	0.10	772.7	36.4	-34.8	Cepheids	1991	Madore
	24.40	±	0.20	758.6	73.2	-66.7	GC velocity dispersion	1992	Paturel
	24.44	±	0.15	772.7	55.3	-51.6	RR Lyrae	1992	Lee
	24.30	±	0.20	724.4	69.9	-63.7	TRGB	1994	Morris et al.
	24.29	±	0.08	719.8	27.0	-26.0	Cepheids	1995	Richer
	24.50	±	0.20	794.3	76.6	-69.9	TRGB	1995	Couture et al.
	24.36	±	0.03	744.7	10.4	-10.2	carbon stars	1995	Brewer et al.
	24.38	±	0.05	751.6	17.5	-17.1	Cepheids	1995	Brewer et al.
	24.19	±	0.10	688.7	32.5	-31.0	RR Lyrae	1995	Huterer
	24.38	±	0.15	751.6	53.8	-50.2	Cepheids	1995	Huterer
	24.56	±	0.12	816.6	46.4	-43.9	SBF	1996	Ajhar et al.
	24.77	±	0.11	899.5	46.7	-44.4	Cepheids	1997	Feast
	24.03	±	0.23	639.7	71.5	-64.3	GCLF	1997	Ostriker & Gnedin
	24.47	±	0.07	783.4	25.7	-24.9	GC isochrone fits	1998	Holland
	24.47	±	0.08	783.8	29.4	-28.4	red clump	1998	Stanek & Garnavich
	24.38	±	0.05	751.6	17.5	-17.1	SBF	1998	Jensen
	24.43	±	0.14	769.1	51.2	-48.0	SBF	1998	Jensen
	24.12	±	0.45	666.8	153.5	-124.8	Faber-Jackson	1999	Di Nella-Courtois et al.
	24.40	±	0.08	758.6	28.5	-27.4	SBF	2001	Joshi
	24.49	±	0.11	790.7	41.1	-39.1	Cepheids	2003	Joshi et al.
	24.50	±	0.10	794.3	37.4	-35.8	RR Lyrae	2004	Brown et al.
	24.47	±	0.07	783.4	25.7	-24.9	TRGB	2004	McConnachie et al.
And I	24.49	±	0.16	790.0	60.4	-56.1	TRGB	1990	Mould
	24.45	±	0.07	776.2	25.4	-24.6	SBF	1992	Caldwell
	24.33	±	0.07	734.5	24.1	-23.3	TRGB	2004	McConnachie et al.

TABLE B.1 CONTINUED

Galaxy	DM [mag]	error [mag]	Distance [kpc]	error(+) [kpc]	error(–) [kpc]	Method	Year	Author
Local Group								
SMC	19.11	± 0.07	66.4	2.2	-2.1	Cepheids	1985	Visvanathan
	19.76	± 0.12	89.7	5.0	-5.0	H II regions	1986	Issa
	18.78	± 0.15	57.0	4.1	-3.8	RR Lyrae	1986	Reid & Strugnell
	18.97	± 0.07	62.2	2.0	-2.0	Cepheids	1986	Caldwell & Coulson
	18.86	± 0.07	59.2	1.9	-1.9	RR Lyrae	1988	Walker & Mack
	18.83		58.3			Cepheids	1988	Feast
	18.83		58.3			Cepheids	1988	Visvanathan
	19.09	± 0.29	65.8	9.4	-8.2	PNLF	1990	Jacoby et al.
	18.64	± 0.27	53.5	7.1	-6.3	eclipsing binaries	1991	Bell
	18.79		57.3			PNLF	1992	Ciardullo & Jacoby
	19.18	± 0.12	68.5	3.9	-3.7	Cepheids	1994	Di Benedetto
	18.85	± 0.28	58.9	8.1	-7.1	Cepheids	1995	Richer
	18.84	± 0.10	58.6	2.8	-2.6	Cepheids	1997	Böhm-Vitense
	18.56	± 0.09	51.5	2.2	-2.1	HB	1998	Udalski
	18.85	± 0.06	58.9	1.6	-1.6	red giant clump	2001	Girardi & Salaris
	18.89	± 0.04	60.0	1.1	-1.1	eclipsing binaries	2003	Harries
	19.07	± 0.12	65.2	3.7	-3.5	Cepheids	2004	Abrahamyan
And IX	24.48	± 0.20	787.0	75.9	-69.3	TRGB	2004	Zucker
	24.42	± 0.07	765.6	25.1	-24.3	TRGB	2004	McConnachie et al.
Sculptor dSph	19.47	± 0.10	78.3	3.7	-3.5	CMD	1977	Kunkel
	19.71	± 0.30	87.5	13.0	-11.3	RR lyrae	1995	Kaluzny
Pisces Dwarf	24.77	± 0.63	899.9	302.9	-226.6	CMD	1983	Christian
	24.54	± 0.21	809.1	82.2	-74.6	TRGB	1995	Lee
	23.90	± 0.30	602.6	89.3	-77.8	TRGB	1996	Tikhonov & Makarova
	24.43	± 0.19	770.2	70.4	-64.5	TRGB	1997	Aparicio
	24.91	± 0.15	959.8	68.6	-64.1	TRGB	1997	Aparicio
	23.98	± 0.07	625.2	20.5	-19.8	various	2001	Miller et al.
	24.43	± 0.07	769.1	25.2	-24.4	TRGB	2004	McConnachie et al.
IC 1613	24.31	± 0.12	727.8	41.4	-39.1	Cepheids	1984	McCatary
	24.27	± 0.10	714.5	33.7	-32.2	Cepheids	1988	Freedman
	24.30	± 0.10	724.4	34.1	-32.6	Cepheids	1990	Freedman
	24.42	± 0.13	765.6	47.2	-44.5	Cepheids	1991	Madore
	24.10	± 0.27	660.7	87.5	-77.2	RR lyrae	1992	Saha
	24.27	± 0.25	714.5	87.2	-77.7	TRGB	1993	Lee
	24.29	± 0.12	721.1	41.0	-38.8	TRGB	1999	Cole et al.
	24.31	± 0.06	727.8	20.4	-19.8	Ceph., RR Lyrae, TRGB	2001	Dolphin et al.
And V	24.55	± 0.12	812.8	46.2	-43.7	CMD	1998	Armandroff et al.
	24.44	± 0.08	772.7	29.0	-27.9	TRGB	2004	McConnachie et al.
And II	24.41	± 0.16	762.1	58.3	-54.1	SBF	1992	Caldwell
	23.83	± 0.42	582.9	124.4	-102.5	CMD	1993	König
	24.17	± 0.06	682.3	19.1	-18.6	HB	2000	Da Costa et al.
	24.05	± 0.06	645.7	18.1	-17.6	TRGB	2004	McConnachie et al.
M 33	24.56		816.6			Cepheids	1974	Sandage
	24.45		776.2			H II regions	1978	de Vaucouleurs
	24.21		695.0			blue supergiant variables	1978	de Vaucouleurs
	24.75		891.3			brightest blue&yellow clusters	1978	de Vaucouleurs
	24.12		666.8			Cepheids	1978	de Vaucouleurs
	24.64		847.2			brightest superassociation	1979	de Vaucouleurs
	24.48		787.0			L index vs. eff. aperture	1979	de Vaucouleurs
	24.85		933.3			L index vs. B_T, log D_0	1979	de Vaucouleurs
	23.90	± 0.20	602.6	58.1	-53.0	M supergiants	1980	Humphreys
	24.76		895.4			Cepheids	1981	Sandage
	24.32	± 0.15	731.1	52.3	-48.8	Cepheids	1983	McAlary
	25.23		1111.7			Cepheids	1983	Sandage
	24.18	± 0.18	685.5	59.2	-54.5	Tully-Fisher	1984	Bottinelli
	24.30	± 0.20	724.4	69.9	-63.7	Cepheids	1985	Madore
	24.10	± 0.20	660.7	63.7	-58.1	Cepheids	1985	Freedman
	24.39	± 0.13	755.1	47.1	-47.1	H II regions	1986	Issa
	24.20	± 0.15	691.8	49.5	-46.2	Cepheids	1987	Christian
	24.60	± 0.10	831.8	39.2	-37.4	LP variables	1987	Kinman
	24.63	± 0.08	843.3	31.6	-30.5	LP variables	1987	Mould
	24.76	± 0.03	895.4	12.5	-12.3	Cepheids	1987	Mould
	24.81	± 0.13	916.2	56.5	-53.2	Cepheids	1987	Mould
	24.00	± 0.15	631.0	45.1	-42.1	Cepheids	1987	Christian
	24.05	± 0.15	645.7	46.2	-43.1	Cepheids	1987	Christian
	24.80		912.0			TRGB	1987	Mould
	24.36	± 0.30	744.7	110.3	-96.1	novae	1988	Della Valle
	24.65		851.1			Cepheids	1988	Sandage

Table B.1 continued

Galaxy	DM [mag]	error [mag]	Distance [kpc]	error(+) [kpc]	error(–) [kpc]	Method	Year	Author
Local Group								
(M33 continued)	24.50	± 0.20	794.3	76.6	-69.9	Cepheids	1988	Freedman
	24.25		707.9			Cepheids	1988	Feast
	24.58	± 0.60	824.1	262.3	-199.0	PNLF	1989	Ciardullo et al.
	24.63	± 0.09	843.3	35.7	-34.2	Cepheids	1990	Freedman
	24.60	± 0.30	831.8	123.2	-107.3	TRGB	1990	Wilson
	24.70	± 0.15	871.0	62.3	-58.1	Cepheids	1991	Metcalfe & Shanks
	24.63	± 0.09	843.3	35.7	-34.2	Cepheids	1991	Madore
	24.64	± 0.09	847.2	35.9	-34.4	Cepheids	1991	Freedman et al.
	24.71	± 0.20	875.0	84.4	-77.0	RR Lyrae	1992	Lee
	24.48	± 0.05	787.0	18.3	-17.9	SBF	1998	Jensen
	24.62	± 0.25	839.5	102.4	-91.3	PNLF	2000	Magrini et al.
	24.50	± 0.06	794.3	22.3	-21.6	TRGB	2004	McConnachie et al.
Phoenix Dwarf	23.24	± 0.38	444.6	85.0	-71.4	CMD	1986	Gratton
	24.90	± 0.30	955.0	141.5	-123.2	Cepheids	1988	Caldwell
	23.50	± 0.50	501.2	129.8	-103.1	CMD	1988	Ortolani
	23.10	± 0.10	416.9	19.6	-18.8	BS	1991	van de Rydt
	23.21	± 0.08	438.5	16.5	-15.9	HB	1999	Held et al.
	23.00	± 0.10	398.1	18.8	-17.9	TRGB	1999	Martinez-Delgado et al.
Fornax dSph	20.59	± 0.22	131.2	14.0	-12.6	CMD	1985	Buonanno
	20.70	± 0.30	138.0	20.5	-17.8	CMD	1995	Beauchamp
	20.70	± 0.12	138.0	7.8	-7.4	TRGB	2000	Saviane et al.
	20.76	± 0.04	141.9	2.6	-2.6	HB	2000	Saviane et al.
LMC	18.38	± 0.02	47.4	0.4	-0.4	eclipsing variables	1970	Gaposchkin
	18.59		52.2			Cepheids	1971	Sandage
	18.10		41.7			BA stars	1973	Divan
	18.31		45.9			SN	1973	Mathewson
	18.05	± 0.10	40.7	1.9	-1.8	MS fitting	1974	Walker
	18.36	± 0.25	47.0	5.7	-5.1	eclipsing variables	1974	Dworak
	18.25		44.7			Cepheids	1977	Eggen
	18.38		47.4			novae	1978	de Vaucouleurs
	18.34		46.6			Cepheids	1978	de Vaucouleurs
	18.17		43.1			RR Lyrae	1978	de Vaucouleurs
	18.32	± 0.30	46.1	6.8	-6.0	BA stars	1978	de Vaucouleurs
	18.69	± 0.15	54.7	3.9	-3.7	Cepheids	1979	Martin
	18.69	± 0.15	54.7	3.9	-3.7	Cepheids	1979	Martin
	18.73	± 0.16	55.7	4.3	-4.0	Hgamma widths	1979	Crampton
	18.53	± 0.13	50.8	3.1	-3.0	OB stars	1979	Crampton
	18.79		57.3			Cepheids	1981	Sandage
	18.50	± 0.10	50.1	2.4	-2.3	Cepheids	1983	Stothers
	18.25	± 0.20	44.7	4.3	-3.9	HB / AGB fitting	1984	Andersen
	18.42	± 0.10	48.3	2.3	-2.2	RR Lyrae	1984	Walker
	18.20	± 0.20	43.7	4.2	-3.8	MS fitting	1984	Schommer
	18.13	± 0.25	42.3	5.2	-4.6	RR Lyrae	1985	Nemec
	18.82	± 0.07	58.1	1.9	-1.8	Cepheids	1985	Visvanathan
	18.40		47.9			AGB fitting	1985	Andersen
	18.42	± 0.20	48.3	4.7	-4.3	MS fitting	1985	Walker
	18.52	± 0.20	50.6	4.9	-4.5	MS fitting	1985	Walker
	18.80	± 0.30	57.5	8.5	-7.4	supergiants	1986	Shobbrook
	18.15		42.7			HB	1986	Andersen
	18.45	± 0.05	49.0	1.1	-1.1	Cepheids	1986	Mathewson
	18.10	± 0.30	41.7	6.2	-5.4	MS / AGB fitting	1986	Mateo
	18.40		47.9			CMD	1986	Chiosi
	18.73	± 0.05	55.7	1.3	-1.3	Cepheids	1986	Laney
	18.37	± 0.15	47.2	3.4	-3.2	RR Lyrae	1986	Reid & Strugnell
	18.65	± 0.07	53.7	1.8	-1.7	Cepheids	1986	Caldwell & Coulson
	18.30	± 0.30	45.7	6.8	-5.9	MS fitting	1986	Conti
	18.15	± 0.12	42.7	2.5	-2.5	HII regions	1986	Issa
	18.47	± 0.17	49.4	4.0	-3.7	Cepheids	1987	Feast
	18.31	± 0.18	45.9	4.0	-3.7	SN	1987	Hoflich
	18.22	± 0.45	44.1	10.1	-8.2	SN	1987	Chugaj
	18.30	± 0.20	45.7	4.4	-4.0	B stars	1987	Shobbrook & Visvanathan
	18.45		49.0			Cepheids	1987	Caldwell
	18.30		45.7			CMD	1987	Jones
	18.40	± 0.20	47.9	4.6	-4.2	MS / AGB fitting	1987	Mateo
	18.30	± 0.20	45.7	4.4	-4.0	CMD	1987	Gratton
	18.42	± 0.15	48.3	3.5	-3.2	TRGB	1987	Reid
	18.10	± 0.30	41.7	6.2	-5.4	CMD	1987	Andersen
	18.20	± 0.20	43.7	4.2	-3.8	MS fitting	1987	Geisler
	18.44	± 0.15	48.8	3.5	-3.3	Cepheids	1987	Walker
	18.57	± 0.05	51.8	1.2	-1.2	Cepheids	1987	Welch

TABLE B.1 CONTINUED

Galaxy	DM [mag]	error [mag]	Distance [kpc]	error(+) [kpc]	error(–) [kpc]	Method	Year	Author
Local Group								
(LMC continued)	18.21		43.9			GC isochrone fits	1988	Mateo
	18.44	± 0.05	48.8	1.1	-1.1	RR Lyrae	1988	Walker
	18.38		47.4			Mira variables	1988	Feast
	18.51	± 0.06	50.4	1.4	-1.4	Cepheids	1988	Stothers
	18.18	± 0.20	43.3	4.2	-3.8	SN	1988	Chilukuri
	18.12	± 0.10	42.1	2.0	-1.9	SN	1988	Wagoner
	18.52		50.6			Cepheids	1988	Feast
	18.52		50.6			Cepheids	1988	Laney & Stobie
	18.26	± 0.20	44.9	4.3	-3.9	RR Lyrae	1989	Clementini
	18.45	± 0.28	49.0	6.7	-5.9	SN	1989	Eastman
	18.42	± 0.04	48.3	0.9	-0.9	Cepheids	1989	Visvanathan
	18.44	± 0.18	48.8	4.2	-3.9	PNLF	1990	Jacoby et al.
	18.70	± 0.22	55.0	5.9	-5.3	novae	1990	Capaccioli
	18.30	± 0.20	45.7	4.4	-4.0	RR Lyrae	1990	Carney
	18.28	± 0.18	45.3	3.9	-3.6	SN	1990	Schmutz
	18.66	± 0.05	54.0	1.3	-1.2	LP variables	1990	Hughes & Wood
	18.40	± 0.15	47.9	3.4	-3.2	novae	1991	de Vaucouleurs
	18.50	± 0.10	50.1	2.4	-2.3	SN	1991	Panagia
	18.20	± 0.40	43.7	8.8	-7.3	PN Hbeta fluxes	1992	Cahn
	18.28		45.3			GC velocity dispersion	1992	Paturel
	18.44		48.8			PNLF	1992	Ciardullo & Jacoby
	18.51	± 0.15	50.4	3.6	-3.4	RR Lyrae	1992	Lee
	18.10	± 0.30	41.7	6.2	-5.4	eclipsing binaries	1993	Bell
	18.69	± 0.13	54.7	3.4	-3.2	Cepheids	1994	Di Benedetto
	18.68	± 0.08	54.5	2.0	-2.0	Cepheids	1994	Di Benedetto
	18.37	± 0.04	47.2	0.9	-0.9	SN	1995	Gould
	18.37	± 0.05	47.2	1.1	-1.1	SN	1995	Richer
	18.56	± 0.08	51.5	1.9	-1.9	SN	1997	Panagia
	18.70	± 0.10	55.0	2.6	-2.5	Cepheids	1997	Feast
	18.54	± 0.08	51.1	1.9	-1.8	eclipsing binaries	1997	Guinan
	18.42	± 0.11	48.3	2.5	-2.4	Cepheids	1997	Böhm-Vitense
	18.46	± 0.06	49.2	1.4	-1.3	Cepheids	1998	Gieren
	18.58	± 0.05	52.0	1.2	-1.2	SN	1998	Panagia
	18.50	± 0.17	50.1	4.1	-3.8	LP variables	1998	Bergeat
	18.49	± 0.07	49.9	1.6	-1.6	eclipsing binaries	1998	Guinan
	18.30	± 0.20	45.7	4.4	-4.0	Cepheids & RR Lyrae	1998	Luri
	18.20	± 0.13	43.7	2.7	-2.5	eclipsing binaries	1998	Udalski
	18.34	± 0.09	46.6	2.0	-1.9	supergiants	1998	Schmidt-Kaler
	18.35	± 0.07	46.8	1.5	-1.5	eclipsing binaries	1998	Guinan
	18.40	± 0.07	47.9	1.6	-1.5	eclipsing binaries	2000	Nelson
	18.70	± 0.20	55.0	5.3	-4.8	carbon stars	2000	D'Antona
	18.60	± 0.11	52.5	2.7	-2.6	Cepheids	2000	Groenewegen
	18.46	± 0.06	49.2	1.4	-1.3	eclipsing binaries	2001	Grönewegen
	18.55	± 0.05	51.3	1.2	-1.2	red giant clump	2001	Girardi & Salaris
	18.37	± 0.07	47.2	1.5	-1.5	red giant clump	2001	Girardi & Salaris
	18.50	± 0.06	50.1	1.4	-1.4	eclipsing binaries	2002	Fitzpatrick
	18.36	± 0.10	47.0	2.2	-2.1	eclipsing binaries	2002	Fitzpatrick
	18.18	± 0.08	43.3	1.6	-1.6	eclipsing binaries	2002	Fitzpatrick
	18.49	± 0.06	50.0	1.5	-1.4	red clump	2002	Alves
	18.49	± 0.12	49.8	2.8	-2.7	red clump	2002	Pietrzynski
	18.54	± 0.10	51.1	2.4	-2.3	red clump	2002	Sarajedini
	18.48	± 0.10	49.7	2.3	-2.2	Cepheids	2002	Bono
	18.55	± 0.02	51.3	0.5	-0.5	Cepheids	2002	Keller
	18.54	± 0.29	51.1	7.3	-6.4	Cepheids	2002	Benedict
	18.46	± 0.12	49.2	2.8	-2.6	SN	2002	Mitchell
	18.49	± 0.06	50.0	1.5	-1.4	red clump	2002	Alves
	18.55	± 0.03	51.3	0.7	-0.7	Cepheids & RR Lyrae	2003	Kovacs
	18.51	± 0.10	50.4	2.4	-2.3	Cepheids	2003	Hoyle
	18.63	± 0.08	53.2	2.0	-1.9	eclipsing binaries	2003	Clausen
	18.58	± 0.08	52.0	2.0	-1.9	eclipsing binaries	2003	Clausen
	18.47	± 0.06	49.4	1.4	-1.3	red clump	2003	Salaris
	18.28	± 0.21	45.3	4.6	-4.2	eclipsing binaries	2003	Ostrov
	18.38	± 0.08	47.4	1.8	-1.7	eclipsing binaries	2003	Ribas
	18.58	± 0.08	52.0	2.0	-1.9	MS fitting	2003	Groenewegen
	18.52	± 0.09	50.5	2.0	-1.9	RR Lyrae	2003	Clementini
	18.57	± 0.12	51.7	2.9	-2.7	Cepheids	2004	Abrahamyan
	18.55	± 0.07	51.3	1.7	-1.6	RR Lyrae	2004	Dall'Ora
	18.48	± 0.08	49.7	1.9	-1.8	Mira variables	2004	Feast
	18.48	± 0.08	49.7	1.9	-1.8	RR Lyrae	2004	Borissova et al.
	18.51	± 0.09	50.4	2.0	-1.9	RR Lyrae	2004	Maio et al.
	18.43	± 0.06	48.5	1.4	-1.3	RR Lyrae	2004	Alcock

TABLE B.1 CONTINUED

Galaxy	DM [mag]		error [mag]	Distance [kpc]	error(+) [kpc]	error(–) [kpc]	Method	Year	Author
Local Group									
Carina Dwarf	19.80	±	0.30	91.2	13.5	-11.8	HB	1983	Mould
	21.10	±	0.30	166.0	24.6	-21.4	RR lyrae	1986	Saha
	19.87			94.2			CMD	1987	Mighell
	20.09	±	0.06	104.2	2.9	-2.8	SBF	1993	Mateo
	20.05	±	0.06	102.3	2.9	-2.8	TRGB	1994	Smecker-Hane
	20.12	±	0.08	105.7	4.0	-3.8	HB	1994	Smecker-Hane
	19.87	±	0.11	94.2	4.9	-4.7	CMD	1996	Mighell
	20.06	±	0.12	102.8	5.8	-5.5	Cepheids	1998	Mateo
	19.96	±	0.06	98.2	2.8	-2.7	red giant clump	2001	Girardi & Salaris
	20.19	±	0.13	109.1	6.7	-6.3	CMD	2002	Dolphin
	20.10	±	0.12	104.7	5.9	-5.6	RR Lyrae	2003	Dall'Ora et al.
Canis Major Dwarf	16.02			16.0				1996	Harris
	15.40	±	0.21	12.0	1.2	-1.2	CMD	2004	Martin et al.
Leo A	26.80	±	0.40	2290.9	463.4	-385.4	brightest blue stars	1984	Demers
	26.00	±	1.00	1584.9	927.0	-584.9	brightest blue&red stars	1986	Sandage
	26.74	±	0.22	2228.4	237.6	-214.7	Cepheids	1994	Hoessel
	24.20	±	0.20	691.8	66.7	-60.9	various	1998	Tolstoy et al.
	24.51	±	0.12	798.0	45.3	-42.9	RR Lyrae	2002	Dolphin et al.
Sextans B	26.20	±	0.20	1737.8	167.7	-152.9	Cepheids	1985	Sandage
	25.64	±	0.38	1342.8	256.8	-215.6	Cepheids	1991	Madore
	25.63	±	0.21	1336.6	135.7	-123.2	Cepheids	1994	Piotto
	25.56	±	0.10	1294.2	61.0	-58.2	TRGB	1997	Sakai
	25.69	±	0.27	1374.0	181.9	-160.7	Cepheids	1997	Sakai
	25.66	±	0.13	1355.2	83.6	-78.8	TRGB	2002	Karachentsev et al.
	25.63	±	0.22	1336.6	142.5	-128.8	TRGB	2002	Mendez et al.
NGC 3109	27.06			2582.3			redshift	1981	Sandage
	25.69			1374.0			Tully-Fisher	1984	Bottinelli
	25.98	±	0.15	1570.4	112.3	-104.8	Cepheids	1985	Demers
	25.34	±	0.10	1169.5	55.1	-52.6	BS	1985	Elias & Frogel
	26.64			2128.1			GC	1986	Blechla
	26.00			1584.9			Cepheids	1988	Sandage
	25.94	±	0.39	1541.7	303.3	-253.5	Cepheids	1991	Madore
	25.50	±	0.20	1258.9	121.5	-110.8	Cepheids	1992	Capaccioli
	25.50	±	0.17	1260.1	102.6	-94.9	Cepheids	1992	Piotto
	26.00	±	0.40	1584.9	320.6	-266.6	PNLF	1992	Richer
	25.45	±	0.15	1230.3	88.0	-82.1	TRGB	1993	Lee
	25.67	±	0.16	1361.4	104.1	-96.7	Cepheids	1997	Musella
	25.62	±	0.10	1330.5	62.7	-59.9	TRGB	1999	Minniti et al.
	25.62	±	0.13	1330.5	82.1	-77.3	TRGB	2002	Karachentsev et al.
	25.52	±	0.24	1270.6	148.5	-132.9	TRGB	2002	Mendez et al.
Antlia Dwarf	25.30	±	0.20	1148.2	110.8	-101.0	TRGB	1997	Whiting
	25.89	±	0.10	1506.6	71.0	-67.8	TRGB	1999	Piersimoni et al.
	25.98	±	0.10	1570.4	74.0	-70.7	TRGB	2001	Castellani
Leo I	21.80	±	0.20	229.1	22.1	-20.2	CMD	1987	Fox
	22.18	±	0.11	272.9	14.2	-13.5	TRGB	1993	Lee
	21.56	±	0.25	205.0	25.0	-22.3	HB	1994	Demers
	22.04	±	0.14	255.9	17.0	-16.0	RR lyrae	2001	Held et al.
	22.05	±	0.28	257.0	35.4	-31.1	TRGB	2002	Mendez et al.
Sextans A	25.60	±	0.20	1318.3	127.2	-116.0	Cepheids	1982	Sandage
	26.20	±	0.20	1737.8	167.7	-152.9	Cepheids	1985	Sandage
	25.78	±	0.15	1432.2	102.4	-95.6	Cepheids	1991	Madore
	25.71	±	0.20	1386.8	133.8	-122.0	Cepheids	1994	Piotto
	25.85	±	0.15	1479.1	105.8	-98.7	Cepheids	1996	Sakai
	25.74	±	0.13	1406.0	86.7	-81.7	TRGB	1996	Sakai
	25.64	±	0.05	1342.8	31.3	-30.6	Cepheids	2002	Dolphin
	25.58	±	0.03	1306.2	18.2	-17.9	Cepheids	2002	Dolphin
	25.61	±	0.07	1324.3	43.4	-42.0	Cepheids & TRGB	2003	Dolphin et al.
Sextans dSph	19.65	±	0.24	85.0	9.9	-8.9	CMD	1990	Irwin
	19.70	±	0.30	87.1	12.9	-11.2	CMD	1991	Mateo
	19.67	±	0.15	85.9	6.1	-5.7	variables	1995	Mateo
	19.90	±	0.06	95.5	2.7	-2.6	TRGB	2003	Lee et al.
Leo II	21.81	±	0.18	230.0	19.9	-18.3	CMD	1983	Demers
	21.66	±	0.32	214.8	34.1	-29.4	RR Lyrae	1993	Demers
	21.66	±	0.21	214.8	21.8	-19.8	TRGB	1995	Lee
	21.55	±	0.18	204.2	17.6	-16.2	HB	1996	Mighell

TABLE B.1 CONTINUED

Galaxy	DM [mag]		error [mag]	Distance [kpc]	error(+) [kpc]	error(–) [kpc]	Method	Year	Author
Local Group									
GR 8	25.00	±	0.30	1000.0	148.2	-129.0	BS / H II	1978	de Vaucouleurs
	25.00	±	0.20	1000.0	96.5	-88.0	BS	1988	Aparicio
	26.75	±	0.35	2238.7	391.5	-333.3	Cepheids	1995	Tolstoy
Ursa Minor Dwarf	19.10	±	0.10	66.1	3.1	-3.0	HB	1985	Olszewski
	19.18	±	0.12	68.5	3.9	-3.7	fiducial fitting	1999	Mighell & Burke
	19.41	±	0.12	76.2	4.3	-4.1	HB	2002	Bellazzini
	19.50	±	0.20	79.4	7.7	-7.0	TRGB	2002	Bellazzini
Draco Dwarf	19.98			99.0			RR Lyrae	1961	Baade
	19.62	±	0.29	84.0	12.0	-12.0	RR Lyrae	1985	Nemee
	19.52	±	0.18	80.0	7.0	-7.0	HB	2001	Aparicio
	19.84	±	0.14	92.9	6.2	-5.8	HB	2002	Bellazzini et al.
	19.92	±	0.27	96.4	12.8	-11.3	TRGB	2002	Bellazzini et al.
	19.40	±	0.17	75.9	6.2	-5.7	RR Lyrae	2004	Bonanos et al.
Milky Way	14.54	±	0.20	8.1	0.8	-0.7	PNLF	1990	Pottasch
	14.61	±	0.18	8.4	0.7	-0.7	RR Lyrae	1992	Lee
	14.60	±	0.59	8.3	2.6	-2.6	radius-SB	1996	Schneider & Buckley
	14.57	±	0.08	8.2	0.3	-0.3	red clump	1998	Stanek & Garnavich
	14.47	±	0.05	7.8	0.2	-0.2	red clump	2001	Girardi & Salaris
	14.62	±	0.05	8.4	0.2	-0.2	red clump	2001	Girardi & Salaris
Sagittarius Dwarf	16.90	±	0.17	24.0	2.0	-1.8	HB	1994	Ibata
	16.71	±	0.10	22.0	1.0	-1.0	RR lyrae	1997	Alcock
	17.10	±	0.15	26.3	1.9	-1.8	TRGB	2004	Monaco et al.
SagDIG	25.30	±	0.50	1148.2	297.3	-236.1	CMD	1987	Cook
	25.13	±	0.20	1061.7	102.4	-93.4	TRGB	1999 a	Karachentsev et al.
	25.36	±	0.18	1180.3	102.0	-93.9	TRGB	2000	Lee & Kim
	25.09	±	0.10	1042.3	49.1	-46.9	TRGB	2002	Karachentsev et al.
NGC 6822	23.40	±	0.11	478.6	24.9	-23.6	Cepheids	1983	McAlary
	23.47	±	0.11	494.3	25.7	-24.4	Cepheids	1983	McGonegal
	23.30	±	0.13	457.1	28.2	-26.6	Cepheids	1985	McAlary
	23.66	±	0.20	539.5	52.1	-47.5	Cepheids	1991	Madore
	23.49	±	0.08	498.9	18.7	-18.0	TRGB	1993	Gallart
	23.62			529.7			Cepheids	1993	Lee
	23.46			492.0			TRGB	1993	Lee
	23.49	±	0.08	498.9	18.7	-18.0	Cepheids	1996	Gallart
	23.40	±	0.10	478.6	22.6	-21.5	TRGB	1996	Gallart
	23.36	±	0.17	469.9	38.3	-35.4	RR Lyrae	2003 b	Clementini et al.
Aquarius Dwarf	25.00	±	0.38	1000.0	191.2	-160.5	Tully-Fisher	1975	Fisher
	24.23	±	0.36	700.2	126.3	-107.0	Tully-Fisher	1979	Fisher
	28.00	±	0.42	3981.1	849.5	-700.1	CMD	1993	Greggio
	24.60	±	0.37	831.8	154.5	-130.3	Tully-Fisher & TRGB	1994	van den Bergh
	24.89	±	0.11	950.6	49.4	-47.0	TRGB	1999	Lee et al.
	24.86	±	0.10	937.6	44.2	-42.2	TRGB	2002	Karachentsev et al.
	25.15	±	0.08	1071.5	40.2	-38.8			
IC 5152	26.15	±	0.20	1698.2	163.8	-149.4	CMD	1999	Zijlstra & Minniti
	26.58	±	0.18	2070.1	178.9	-164.7	TRGB	2002	Karachentsev et al.
Tucana Dwarf	24.70	±	0.10	871.0	41.0	-39.2	RR lyrae	1996	Lavery
	24.69	±	0.16	867.0	66.3	-61.6	TRGB	1996	Saviane et al.
	24.72	±	0.20	879.0	84.8	-77.3	CMD	1996	Castellani
UKS 2323-326	24.97	±	0.37	986.3	183.2	-154.5		1988	Tully
	26.59	±	0.12	2079.7	118.2	-111.8	TRGB	1999	Lee & Byun
And VII	24.41	±	0.10	762.1	35.9	-34.3	TRGB	2004	McConnachie et al.
Pegasus Dwarf	25.50	±	0.38	1258.9	240.8	-202.1	TRGB	1983	Christian
	27.00			2511.9			BS	1986	Sandage
	26.22	±	0.20	1753.9	169.2	-154.3	Cepheids	1990	Hoessel
	24.90	±	0.10	955.0	45.0	-43.0	TRGB	1994	Aparicio
	25.13	±	0.11	1061.7	55.2	-52.4	TRGB	1995	Lee
	24.40	±	0.37	760.0	141.2	-119.1	TRGB	1998	Callagher
	24.82	±	0.07	920.4	30.2	-29.2	TRGB	2004	McConnachie et al.
Pegasus dSph	24.45	±	0.10	776.2	36.6	-34.9	CMD	1999	Armandroff et al.
	24.60	±	0.20	831.8	80.2	-73.2	TRGB	1999	Grebel & Guhathakurta
	24.56	±	0.07	815.0	25.0	-25.0	RR lyrae	2002	Pritzl et al.
	24.47	±	0.07	783.4	25.7	-24.9	TRGB	2004	McConnachie et al.

TABLE B.1 CONTINUED

Galaxy	DM [mag]	error [mag]	Distance [kpc]	error(+) [kpc]	error(–) [kpc]	Method	Year	Author
Local Group?								
ESO 352-002	–	–	–	–	–	–	–	–
Anon 0106+21	–	–	–	–	–	–	–	–
Anon 0107+01	–	–	–	–	–	–	–	–
ESO 416-012	–	–	–	–	–	–	–	–
IC 1947	–	–	–	–	–	–	–	–
ESO 056-019	–	–	–	–	–	–	–	–
ESO 318-013	–	–	–	–	–	–	–	–
ESO 269-070	–	–	–	–	–	–	–	–
IC 4247	–	–	–	–	–	–	–	–
KKR 25	26.35	± 0.14	1862.1	124.0	-116.3	TRGB	2001	Karachentsev et al.
IC 4739	–	–	–	–	–	–	–	–
IC 4789	–	–	–	–	–	–	–	–
NGC 6789	26.61		2100.0			Hubble constant	1998	Karachentsev & Makarov
	26.65	± 0.30	2138.0	316.7	-275.9	TRGB	2000	Drozdovsky & Tikhonov
	27.80	± 0.31	3630.8	557.2	-483.0	TRGB	2001	Drozdovsky et al.
IC 4937	–	–	–	–	–	–	–	–
IC 5026	–	–	–	–	–	–	–	–
Capricorn Dwarf	–	–	–	–	–	–	–	–
Anon 2259+12	–	–	–	–	–	–	–	–
ESO 347-008	–	–	–	–	–	–	–	–
Field galaxies?								
UGC 3974	28.57	± 0.15	5176.1	370.2	-345.5	TRGB	2003 a	Karachentsev et al.
NGC 2915	28.62	± 0.48	5300.0	1300.0	-1300.0	BS	1994	Meurer et al.
	27.89	± 0.26	3784.4	481.4	-427.0	TRGB	2003 a	Karachentsev et al.
UGC 6456	28.25	± 0.10	4466.8	210.5	-201.0	TRGB	1998	Lynds et al.
	28.23		4425.9			TRGB	1999	Schulte-Ladbeck et al.
	28.19	± 0.04	4345.1	80.8	-79.3	TRGB	2002	Mendez et al.
UGC 7131	30.80		14454.4			BS	1998	Makarova et al.
IC 3104	26.78	± 0.18	2269.9	196.2	-180.6	TRGB	2002	Karachentsev et al.
Circinus Galaxy	27.24		2800.0			H I velocity	2000	Henning et al.
IC 4662	26.51	± 0.21	2000.0	200.0	-200.0	various	1990	Heydari-Malayeri et al.
IC 342 / Maffei group								
KKH 5	28.15	± 0.17	4265.8	347.4	-321.2	TRGB	2003 a	Karachentsev et al.
KKH 6	27.85		3720.0			Hubble relation	2003 c	Karachentsev et al.
Cassiopeia 1	24.50	± 0.37	794.3	147.6	-124.4	CM	1996	Tikhonov
	26.15	± 0.39	1698.2	334.1	-279.2	BS	1996	Karachentsev
	27.59		3300.0			group membership	2003 c	Karachentsev et al.
KKH 11	27.39		3000.0			group membership	2003 c	Karachentsev et al.
KKH 12	27.39		3000.0			group membership	2003 c	Karachentsev et al.
MB1	28.78		5700.0				1996	Karachentsev
	27.39		3000.0			group membership	2003 c	Karachentsev et al.
Maffei 1	26.65	± 1.00	2138.0	1250.5	-789.0	Faber-Jackson	1983	Buta
	28.10	± 0.42	4168.7	889.6	-733.1	SBF	1993	Luppino & Tonry
	28.09	± 0.51	4150.0	1100.0		Dn-s	1993	Luppino & Tonry
	28.20	± 0.30	4365.2	646.7	-563.3	AGB	2001	Davidge & van den Bergh
	27.39	± 0.21	3010.0	300.0	-300.0	Dn-s	2003	Fingerhut et al.
MB2	–	–	–	–	–	–	–	–
Maffei 2	26.77	± 0.40	2259.4	457.0	-380.1		1994	Tikhonov
	27.24		2800.0			Tully-Fisher	2003 c	Karachentsev et al.

TABLE B.1 CONTINUED

Galaxy	DM [mag]	error [mag]	Distance [kpc]	error(+) [kpc]	error(–) [kpc]	Method	Year	Author
IC 342 / Maffei group								
Dwingeloo 2	28.12		4200.0				1996	Karachentsev
	27.39		3000.0			group membership	2003 c	Karachentsev et al.
MB3	27.39		3000.0			group membership	2003 c	Karachentsev et al.
Dwingeloo 1	28.22		4400.0				1996	Karachentsev
	27.24		2800.0			Tully-Fisher	2003 c	Karachentsev et al.
KK 35	27.50	± 0.22	3162.3	337.2	-304.7	TRGB	2003 c	Karachentsev et al.
IC 342	25.90	± 0.39	1513.6	297.8	-248.8	BS / H II	1971	Ables
	29.51		7979.9			H II	1974 b	Sandage & Tammann
	27.34	± 0.25	2937.6	358.4	-319.5	BS / H II	1978	de Vaucouleurs
	26.32	± 0.15	1836.5	131.3	-122.6	various	1989	McCall
	26.60	± 0.40	2089.3	422.6	-351.5	BS	1993	Karachentsev
	27.58	± 0.18	3281.0	283.6	-261.0	Cepheids	2002	Saha et al.
UGCA 86	27.12	± 0.15	2654.6	189.9	-177.2	BS	1996	Karachentsev
	26.70		2187.8			TRGB	2003 c	Karachentsev et al.
Camelopardalis A	26.38	± 0.20	1888.0	182.1	-166.1	TRGB	1999 b	Karachentsev et al.
	27.97	± 0.26	3926.4	499.4	-443.1	TRGB	2003 c	Karachentsev et al.
NGC 1569	26.19	± 0.39	1729.8	340.3	-284.4	BS	1996	Karachentsev
	26.45		1950.0			TRGB	2003	Makarova
UGCA 92	26.25	± 0.39	1778.3	349.9	-292.3	BS	1996	Karachentsev
	26.28		1800.0			BS	1997	Karachentsev
NGC 1560	27.37	± 0.41	2978.5	619.0	-512.5	BS	1991	Karachentsev
	27.69	± 0.23	3451.4	385.6	-346.9	TRGB	2003 c	Karachentsev et al.
Camelopardalis B	27.39		3000.0				1996	Karachentsev
	27.62	± 0.21	3342.0	339.3	-308.1	TRGB	2003 c	Karachentsev et al.
UGCA 105	27.54	± 0.28	3221.1	443.3	-389.7	BS	1996	Karachentsev
	27.49	± 0.22	3147.7	335.6	-303.3	TRGB	2002	Karachentsev
KKH 34	28.32	± 0.17	4613.2	375.7	-347.4	TRGB	2003 a	Karachentsev et al.
KKH 37	27.36		2970.0			Hubble relation	2003 c	Karachentsev et al.
NGC 2366	27.52		3190.0			TRGB	2002	Karachentsev
DDO 44	27.52		3190.0			TRGB	2002	Karachentsev
NGC 2403	27.55	± 0.16	3235.9	247.4	-229.9	various	1968	Sandage
	26.70		2187.8			various	1976	Madore
	27.34	± 0.55	2937.6	846.8	-657.3	brightest superassociation	1979	de Vaucouleurs
	27.16	± 0.40	2704.0	546.9	-454.9	luminosity index	1979	de Vaucouleurs
	27.09	± 0.20	2618.2	252.6	-230.4	various	1979	de Vaucouleurs
	27.36	± 0.17	2964.8	241.4	-223.3	Tully-Fisher	1984	Bottinelli
	28.15	± 0.20	4265.8	411.6	-375.3	Cepheids	1984	McAlary
	27.66		3404.1			various	1984	Sandage
	26.94	± 0.20	2443.4	235.7	-215.0	various	1984	McCall
	27.11	± 0.20	2642.4	254.9	-232.5	various	1984	McCall
	27.24	± 0.25	2805.4	342.3	-305.1	various	1985	Rowan-Robinson
	27.21	± 0.26	2766.9	351.9	-312.2	Tully-Fisher	1985	Bottinelli
	27.76		3564.5			various	1987	Sandage
	27.51	± 0.24	3176.9	371.3	-332.4	Cepheids	1988	Freedman
	27.30	± 0.20	2884.0	278.2	-253.8	various	1991	Metcalfe & Shanks
	27.59		3300.0			Cepheids	2002	Karachentsev
Cassiopeia dSph	24.50	± 0.10	794.3	37.4	-35.8	TRGB	2003 c	Karachentsev et al.
	24.40	± 0.20	758.6	73.2	-66.7	TRGB	1999	Grebel & Guhathakurta
Sculptor group								
Sculptor dIrr	27.07	± 0.58	2600.0	800.0	-800.0		1977	Laustsen (Heisler98)
	26.87	± 0.40	2365.9	478.5	-398.0		1988	Tully
	27.30	± 0.53	2880.0	800.0	-800.0	various	1988	Puche & Carignan
	28.06		4100.0			Tully-Fisher	2003 b	Karachentsev et al.
NGC 55	27.20	± 0.41	2754.2	572.4	-473.9	CMD	1978	de Vaucouleurs
	25.64	± 0.13	1340.3	82.7	-77.9	carbon stars	1985	Pritchet
	26.10	± 0.25	1660.0	200.0	-200.0	various	1988	Puche & Carignan
	26.28		1800.0			Tully-Fisher	2003 b	Karachentsev et al.
ESO 410-G005	26.42	± 0.20	1923.1	185.5	-169.2	TRGB	2000	Karachentsev et al.

TABLE B.1 CONTINUED

Galaxy	DM [mag]		error [mag]	Distance [kpc]	error(+) [kpc]	error(–) [kpc]	Method	Year	Author
Sculptor Group									
NGC 59	28.21	±	0.07	4385.3	143.7	-139.1	SBF	1998	Jerjen et al.
Scl-dE1 (SC22)	27.13	±	0.12	2666.9	151.5	-143.4	SBF	1998	Jerjen et al.
	28.12	±	0.23	4207.3	470.1	-422.8	TRGB	2003 b	Karachentsev et al.
ESO 294-010	26.17	±	0.08	1714.0	64.3	-62.0	SBF	1998	Jerjen et al.
	26.42	±	0.10	1923.1	90.6	-86.6	TRGB	2002	Karachentsev et al.
IC 1574	28.46	±	0.26	4920.4	625.9	-555.2	TRGB	2003 b	Karachentsev et al.
NGC 247	27.68			3435.6			H II regions	1974 b	Sandage & Tammann
	26.64	±	0.40	2128.1	430.4	-358.0		1988	Tully
	27.02	±	0.39	2530.0	500.0	-500.0	various	1988	Puche & Carignan
	28.06			4090.0			Tully-Fisher	2003 b	Karachentsev et al.
NGC 253	23.80			575.4			BS	1946	Duncan
	26.57			2060.0			dark cloud	1982	Issa
	27.06	±	0.52	2580.0	700.0	-700.0	various	1988	Puche & Carignan
	26.80	±	0.40	2290.9	463.4	-385.4	BS	1990	Davidge
	27.00	±	0.41	2511.9	522.0	-432.2	BS	1991	Davidge
	27.98	±	0.21	3944.6	400.5	-363.6	TRGB	2003 b	Karachentsev et al.
	27.73	±	0.14	3515.6	234.1	-382.3	PNLF	2004	Rekola et al.
ESO 540-030	27.52	±	0.08	3191.5	119.8	-115.4	SBF	1998	Jerjen et al.
	27.66	±	0.22	3404.1	363.0	-328.0	TRGB	2003 b	Karachentsev et al.
ESO 540-031	27.62	±	0.16	3342.0	255.5	-237.4	TRGB	2003 b	Karachentsev et al.
ESO 540-032	26.72	±	0.13	2208.0	136.2	-128.3	SBF	1988	Jerjen et al.
	26.72	±	0.13	2210.0	140.0			1988	Puche
	27.64	±	0.14	3372.9	224.6	-210.6	TRGB	2001	Jerjen & Rejkuba
	27.67	±	0.17	3419.8	278.5	-257.5	TRGB	2003 b	Karachentsev et al.
NGC 300	26.40			1905.5			star counts	1962	de Vaucouleurs
	28.33			4634.5			luminosity class	1975	Sandage
	26.69	±	0.25	2177.7	265.7	-236.8	H II regions	1978	Melnick
	26.80			2290.9			H II regions	1978	de Vaucouleurs
	27.10			2630.3			star counts	1978	de Vaucouleurs
	26.70	±	0.40	2187.8	442.5	-368.1	H II regions	1979	de Vaucouleurs
	26.25			1778.3			lambda vs. eff. aperture	1979	de Vaucouleurs
	26.55	±	0.40	2041.7	413.0	-343.5	lambda vs. diameter	1979	de Vaucouleurs
	26.90			2398.8			redshift	1981	Sandage
	25.80	±	0.50	1445.4	374.3	-297.3	brightest red giants	1982	Graham
	25.85	±	0.34	1479.1	250.7	-214.4	PNLF	1983	Lawrie
	26.33	±	0.23	1845.0	206.1	-185.4	Tully-Fisher	1983	Bottinelli
	26.32			1836.5			brightest blue stars	1983	de Vaucouleurs
	26.09	±	0.20	1652.0	159.4	-145.4	Cepheids	1984	Graham
	25.87			1492.8			carbon stars	1985	Richer
	26.35	±	0.25	1862.1	227.2	-202.5	Cepheids	1987	Madore
	26.40			1905.5			carbon stars	1987	Madore
	26.28	±	0.23	1800.0	200.0	-200.0	various	1988	Puche & Carignan
	26.40	±	0.20	1905.5	183.8	-167.7	Cepheids	1988	Walker
	25.78	±	0.10	1432.2	67.5	-64.5	Cepheids	1989	Visvanathan
	26.50	±	0.20	1995.3	192.5	-175.6	Cepheids	1990	Freedman
	26.66	±	0.10	2147.8	101.2	-96.7	Cepheids	1992	Freedman et al.
	26.90	±	0.40	2398.8	485.2	-403.6	PNLF	1996	Soffner
ESO 295-029	–		–	–	–	–	–	–	–
NGC 625	27.16			2700.0			Tully-Fisher	2003 b	Karachentsev et al.
ESO 245-005	28.23	±	0.23	4425.9	494.5	-444.8	TRGB	2003 b	Karachentsev et al.
KK 258	–		–	–	–	–	–	–	–
UGCA 438	26.59	±	0.12	2080.0	120.0			1999	Lee
	26.74	±	0.15	2228.4	159.4	-148.7	TRGB	2002	Karachentsev et al.
ESO 471-006	28.15	±	0.27	4265.8	564.8	-498.8	TRGB	2003 b	Karachentsev et al.
ESO 149-003	29.03			6400.0			Tully-Fisher	2003 b	Karachentsev et al.
NGC 7793	27.21	±	0.41	2766.9	575.0	-476.1		1988	Tully
	27.64	±	0.18	3380.0	300.0	-300.0	various	1988	Puche & Carignan
	27.96	±	0.24	3908.4	456.7	-409.0	TRGB	2003 b	Karachentsev et al.

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APPENDIX C
The Extended Local Group on the WWW

The Extended Local Group of galaxies contains the most frequently studied galaxies on the sky. As a public service to everybody interested in the contents of the group or qualities of galaxies therein, some World Wide Web pages have been set up as a by-product of this thesis work.

The entry page gives a brief introduction into what the Local Group of galaxies and the Extended Local Group of galaxies are and how dynamical studies are connected to them. The core of the site is, however, a complete table of all Extended Local Group galaxies with their coordinates in equatorial (J2000.0), galactic, supergalactic and supergalactic cartesian coordinate systems. Also given are the mean distances of the galaxies in distance moduli and in kiloparsecs, heliocentric and galactocentric radial velocities, classification in coding of de Vaucouleurs et al. (1991, The Third Reference Catalogue of Bright Galaxies, Vol. I, Springer-Verlag, New York), and an estimate of group membership. Another table lists all names the galaxies are known by. Galaxy names in both tables function as links to individual pages where a more detailed description of each galaxy is given. There are also 2-D and 3-D images of the distribution of Extended Local Group galaxies in the supergalactic cartesian coordinate system.

The Extended Local Group WWW page can be found from the Tuorla Observatory web site at **http://www.astro.utu.fi/EGal/elg/ELG.html**.

Original publications