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ASTRONOMY AND ASTROPHYSICS

Standard photometric diameters of galaxies

II. Reduction of the ESO, UGC, MCG catalogues

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Summary. Using an improved version of the catalogue of 237 standard photometric diameters of galaxies, compiled in Fouqué and Paturel (1983), we reduce the visual diameters of galaxies in great catalogues (ESO, UGC and MCG) to this standard system. We show that this needs introduction of an additive constant 0.'3 to the visual diameters, to put them on a photometric system. Bypass products of this study are conversion relations for the axis ratios, comparison of RC2 with our standard system (and evidence of problems with the RC2 axis ratios), discovery of inhomogeneities in the Holmberg (1958) system of diameters, preliminary results for the particular case of low surface brightness (LSB) galaxies and for diameters in other photometric bands (V diameters of Watanabe, 1983). A rather complete study of $K_D = \partial \log D / \partial B$ is also given, because necessary to reduce photometric systems at different levels between them.

Key words: galaxies – catalogues – diameters – standard

Introduction

A new paper giving conversion relations between systems of galaxy diameters. Why? The homogenization of data for galaxy diameters is not a recent problem and a comparison of various past results with ours is given in the course of this paper, and, on graphical form, in the conclusion (Fig. 12). The first way of approaching this problem was to find in catalogues of diameters, one "better" than others and to reduce the latter to the former (see for instance Paturel, 1975a). With the progress of photometry, it was understood independently by Paturel (1975b) and de Vaucouleurs (de Vaucouleurs et al., 1976, hereafter RC2), that a better way was to define a system of standard diameters from photometric measurements, and to reduce other systems of diameters (mainly visual) to this standard system. The Paturel standard system was based on 15 measurements of Sc galaxies, with diameters in agreement with the compilation of 118 standards used in RC2 (de Vaucouleurs, 1977a). It should be noted that RC2 diameters for standard galaxies are weighted mean of the photometric measurements with the reduced diameters from catalogues. Later, people used mainly RC2 as a standard system and reduce new diameters to this system (see for instance Lauberts, 1982).

In the first paper of this series (Fouqué and Paturel, 1983) we improved the standard system of RC2, mainly by supplementing it to 237 galaxies. We added to this first list, measurements of LSB galaxies by Romanishin et al. (1983) and we have revised this system by comparison with diameters in large catalogues, thus rejecting aberrant "standard" measurements from only one source when catalogue measurements agree together but disagree with the "standard" value. Details of the modifications of the standard catalogue of Paper I are reported in Table 1, defining a standard system of 250 galaxies.

This more extended catalogue (2 times the RC2 basic system) does not justify alone a revision of conversion relations. A very important problem, well outlined in Fisher and Tully (1981), is illustrated in Fig. 1, which displays, for 238 galaxies of the Holmberg (1958) catalogue, the ratio D_{HOL}/D_{UGC} vs. D_{UGC},

Table 1. Revision of the standard catalogue of Paper 1

Ident. (a)	T (b)	$\log D_{25}$ (c)	$\log D26.6$ (d)	Remarks (e)
I467	5			New morphological type
N3432				Rejected
N5194				Rejected
N5846				Rejected
N7331	3			New morphological type
N45	8	1.766 1	1.982 1	Added LSB galaxy
U4841	7	1.457 1	1.637 1	ibid.
U4922	−9	1.392 1	1.564 1	ibid.
N3913	7	1.336 1	1.491 1	ibid.
U6922	−9	1.156 1	1.421 1	ibid.
U6956	9		1.322 1	ibid.
U6983	6	1.472 1	1.630 1	ibid.
N4411A	8	1.279 1	1.442 1	ibid.
N4411B	8	1.409 1	1.501 1	ibid.
U7557	−9	1.386 1	1.572 1	ibid.
U7685	8	1.510 1	1.666 1	ibid.
U7911	9	1.409 1	1.519 1	ibid.
D142	9	1.457 1	1.656 1	ibid.
D146	10	1.491 1	1.630 1	ibid.
N5774	7	1.472 1	1.602 1	ibid.
U11868	−9	1.239 1	1.447 1	ibid.

[a] Identification NGC (N), IC (I), UGC (U), DDO (D)
[b] Morphological type (coded as in paper I)
[c] Logarithm of the major axis diameter at 25 mag arcsec^{-2} in B-band
[d] Logarithm of the major axis diameter at 26.6 mag arcsec^{-2} in B-band
[e] Remarks concerning the modification

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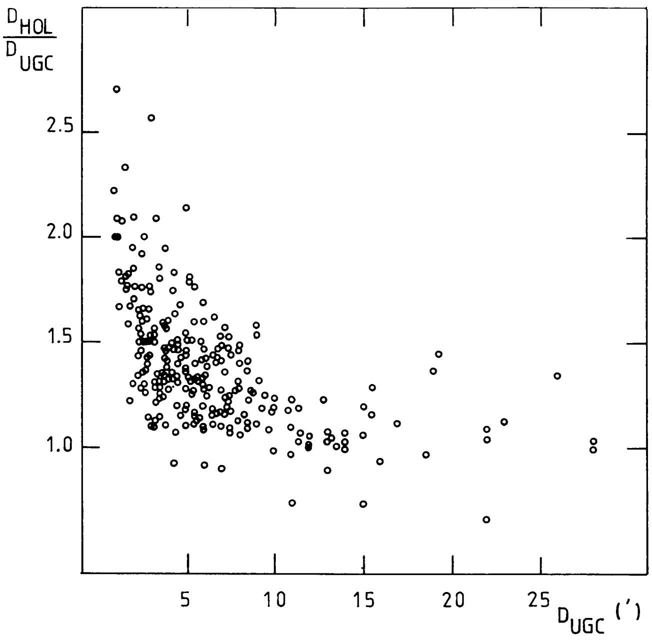

Fig. 1. Ratio D_{HOL}/D_{UGC} vs. D_{UGC}. The variation of this ratio shows that, at least, one of these systems of diameters is not an isophotal system

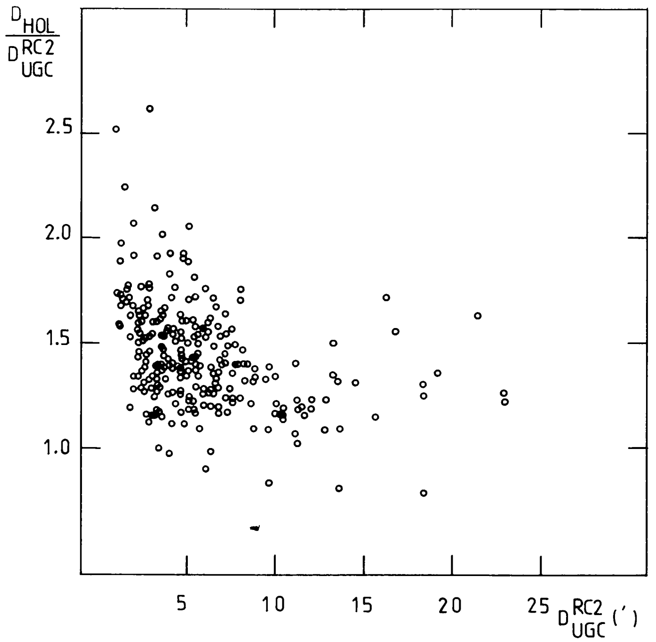

Fig. 3. This figure is the same as the first one, but the UGC diameters are corrected according to the relations given in the Second Reference Catalogue (RC2). The trend does not disappear

where D_{UGC} is the diameter in the Nilson (1973, 1974) catalogues. The large variation of the ratio (from 1 to 2) means that one of the two systems, or both, is not measured at a constant level of limiting surface brightness, and that use of one or the other in, for instance, the extragalactic distance scale, does not lead to the same distances. Moreover, the correlation with diameter, in the sense that a smaller diameter leads to a larger ratio, leads to a systematic error in the extragalactic distance scale (EDS) if the bad system is employed. One can think that this effect is due

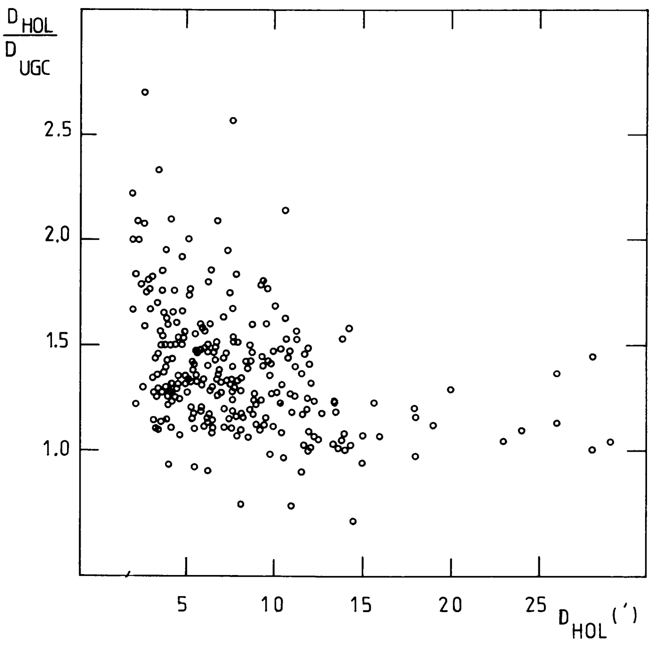

Fig. 2. The same ratio as in Fig. 1 is plotted vs. D_{HOL}. The same trend is visible. This shows that it is not due to the interdependence of the quantities plotted on both axes

to the correlation of errors in Fig. 1, because we plot two interdependent quantities, via D_{UGC}. So, in Fig. 2, we plot the same ratio vs. D_{HOL}. The same trend remains visible. If now we use the relations given in RC2 to correct the UGC diameters, we obtain the Fig. 3, which seems hardly better than Fig. 1, and anyhow shows that the conversion relation in RC2 does not solve our problem. So we are justified in beginning a new search of improved conversion relations to reduce diameters in great catalogues of galaxies, in particular the newly published ESO catalogue (Lauberts, 1982), to our standard photometric system.

The catalogues reduced in this paper are mainly catalogues of visual diameters, which means diameters obtained via eye-estimated limit of the galaxy. This needs first an empirical comparison of eye-estimations and true photometric systems, made in Sect. 1. Then we must know how to reduce a photometric system at a given level, for example the mean level of the catalogue, to our standard system at the 25 mag arcsec^{-2} level. This point needs good knowledge of the quantity $K_D = \partial \log D/\partial B$, which is studied in Sect. 2.

So we get "theoretical" relations to reduce visual diameters. Now, determining the mean levels of limiting surface brightness of our catalogues in Sect. 3, we can compare "theoretical" predictions and experimentally derived relations in Sect. 4. In Sect. 5 we make a simpler study for the axis ratios, following the same ideas. In Sect. 6, we study the rather particular case of the microphotometric measurements of the Holmberg catalogue in order to decide finally if it is justified to use it as a good system, as it has been done many times in the past.

1. Reduction of visual measurements of diameters to a photometric system

The study of deviations of visual measurements, relative to photometric measurements, which are defined by a *constant* limiting

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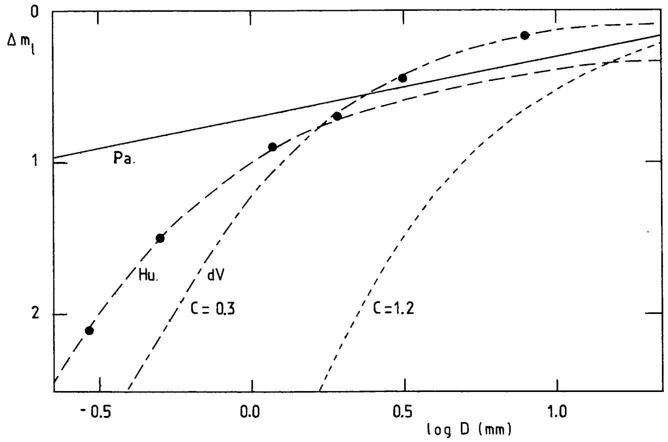

Fig. 4. Variation of the limiting surface brightness as a function of the measured diameter. The dots represent measurements by Hubble. The different curves represent different approximations used to correct this effect: Hubble, 1932 (Hu); de Vaucouleurs, 1959 (dV for $C = 0.3$), Paturel, 1975b (Pa)

surface brightness, begins with Hubble (1932). He made a laboratory experiment with images smaller and smaller to determine the deviation of measurements from a constant limiting surface brightness, the value of which was determined from greater diameters. His results, shown in Fig. 4, are plotted with different laws to represent them. Hubble represented them with an hyperbolic model with two asymptotes: one of constant surface brightness, for great diameters, and one of constant luminosity, for very small diameters. This model has been proved later to apply as a criterion of detection and inclusion of galaxies in catalogues: for small galaxies, the limiting quantity is magnitude, but for extended galaxies, it is surface brightness. The Shapley-Ames catalogue of galaxies (Shapley and Ames, 1932) provides a good proof of these competing limits.

Later, in 1959, de Vaucouleurs envisaged again this problem to reduce various measurements of galaxy diameters to measurements from Heidelberg Observatory. He made that with a law of the following form:

$$D_2 = AD_1 + B \tag{1}$$

where D_1 and D_2 are measured on the plates in millimeters. The constant A accounts for different scales of the plates and the constant B for a photovisual effect. This effect can be explained in the following way: the limit of the galaxy, judged from eye, corresponds to the smallest perceptible excess of photographic density above the density fluctuations due to the graininess of the plate. When the scanned area decreases, the *relative* density fluctuations increase, and so this requested density excess. Thus the limiting surface brightness decreases (dimensions of small objects are underestimated in visual estimations, relatively to photometric measurements).

G. de Vaucouleurs showed that this effect was qualitatively the same as the Hubble effect, and, for spiral galaxies, quantitatively also. B is dependent of the scale S (in arcmin/mm) of the plate, so that relation (1) can be rewritten as:

$$D_2 = A(D_1 + D_0)$$

where D_0 is a measurement (in mm) of the above effect. The value found by de Vaucouleurs was $D_0 = 0.3$ mm, independent of the morphological type of the galaxy, so that, for the scale of the Palomar Sky Survey ($S = 1$ arcmin/mm),

$$C = SD_0 = 0'.3\,.$$

We can see in Fig. 4 that this value provides indeed a good representation of Hubble measurements for diameters in our range of interest ($D \geqq 1$ mm). If we try to explain in this way all the effect shown in Fig. 1, the required constant C to correct UGC measurements is about $1'.2$, but this is in disagreement with the Hubble measurements, as can be seen from Fig. 4.

More recently (Bottinelli et al., 1973; Paturel, 1975a), appeared laws of conversion of the following form:

$$\log D_2 = a \log D_1 + b$$

where a value of a different from 1 was a representation of the so-called "diameter effect", introduced by Paturel (1975b), and which is the same as our above effect. It can be seen from Fig. 4 that this representation of our effect does not match the Hubble measurements. So in RC2, de Vaucouleurs reintroduced his constant under the following form:

$$\log D_2 = a \log(D_1 + C) + b \tag{2}$$

but tried to determine experimentally the 3 parameters from a fit of (2). He found $0'.3$ for MCG diameters (Vorontsov-Velyaminov, 1962–1964) but $0'$ for UGC, probably because of too few points. He did not want to apply the $0'.3$ correction to MCG diameters smaller than $0'.7$, but later, Bigay and Paturel (1980) have shown that this creates a distortion and have recommended to apply the $0'.3$ correction to *all* MCG diameters. Furthermore, de Vaucouleurs found values of a differing from 1, so his formulas in RC2 represent two times the same effect: with a differing from 1 and C differing from 0. This is not very satisfactory, from our point of view.

Our way of reasoning is the following: from Hubble's (1932) experiments and de Vaucouleurs's (1959) results, we adopt a value of $C = 0'.3$ to reduce visual measurements of diameters in ESO, MCG and UGC catalogues to a photometric system. If then, from experimental fits, we find values of a close to 1, we are satisfied with our empirical model. If not, we will vary the C constant to find values of a close to 1 for the *three* catalogues, because in our model, C must be the same for all visual measurements made on plates of the same scale, which is the case for UGC and MCG (Palomar Sky Survey, scale: 1.12 arcmin/mm) and ESO (Quick Blue Survey, scale: 1.13 arcmin/mm). If this cannot be achieved, our model must be revised.

2. Conversion of diameters at a level B_1 to diameters at 25 mag arcsec^{-2}

2.1. Theoretical conversion relation

Let us now suppose that we have diameters D_1 in a photometric system, i.e. measured at a constant level of limiting surface brightness B_1. These diameters can be true measurements or reduced diameters from visual measurements, as explained in Sect. 1. Our problem is now to convert these diameters to our standard system of D_{25} diameters, measured at the limiting surface brightness $B = 25$ mag arcsec^{-2} level. To achieve this purpose, we can use a Taylor formula, if the 1 level is not too far from the 25 one. We can then write:

$$\log D_1 = \log D_{25} + (B_1 - 25)(\partial \log D/\partial B)_{25}$$
$$+ (B_1 - 25)^2/2(\partial^2 \log D/\partial B^2)_{25} + \cdots$$

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so with our notation $K_D(25) = (\partial \log D/\partial B)_{25}$

$$\log D_1 = \log D_{25} + (B_1 - 25) K_D(25) + (B_1 - 25)^2/2 (\partial K_D/\partial B)_{25} + \cdots . \quad (3)$$

So in order to convert our diameters, we need to know $K_D(25)$ and its derivatives, and the photometric level of our diameters B_1.

2.2. Study of $K_D(25)$ and its derivatives

For that study, we have to know the variation of diameter with isophotal level around the 25 mag arcsec^{-2} level. This depends on the morphological type T of the galaxy (T is numerically coded according to the RC2). At this step, we can adopt the $r^{1/4}$ law of de Vaucouleurs (1948) for elliptical galaxies, the exponential law (Patterson, 1940) for late type spiral galaxies, and a linear combination of both for intermediate type galaxies (de Vaucouleurs, 1977b). In this study, we will adopt a pure exponential model for $T=5$ to $T=10$ galaxies, and a pure $r^{1/4}$ model for $T=-5$ galaxies. For other morphological types, we will use a reduced type t defined by:

$$t = T/5 . \quad (4)$$

So, we can write the variation of B_1 with D_1 on the following form:

for $t=-1$

$$B_1 = B_e + 8.327 ((D_1/D_e)^{1/4} - 1) \quad (5a)$$

for $t \geqq +1$

$$B_1 = B_e + 1.822 (D_1/D_e - 1) \quad (5b)$$

for $-1 < t < +1$

$$B_1 = (1-t)/2 B_1(-1) + (1+t)/2 B_1(1) \quad (5c)$$

where we suppose that the coefficients of the linear combination are linearly dependent on the reduced morphological type t. B_e is the isophotal level of the effective isophote (which contains half of the light), and D_e the corresponding diameter of the galaxy. D_e is not measured for many galaxies, but a related quantity, A_e (effective aperture) is known for 753 galaxies in RC2. Our adopted relation between these quantities is:

$$\log D_e = \log A_e - 0.55 (\log R_{25})^2 \quad (6)$$

from de Vaucouleurs and Corwin (1977), where R_{25} is the axis ratio at the 25 mag arcsec^{-2} level, from RC2. For a discussion of this formula and of the 0.55 coefficient, see Olson and de Vaucouleurs (1981) and Fouqué (1982).

From the relations (5), we can now calculate $K_D(l)$ and its derivatives for any reduced morphological type t. We find:

$$K_D(l) = 1/\ln 10 (\alpha \rho_1 + \beta \rho_1^{1/4}) \quad (7)$$

$$(\partial K_D/\partial B)_1 = -K_D^3 (\ln 10)^2 (\alpha \rho_1 + \beta/4 \rho_1^{1/4}) \quad (8)$$

where $\alpha = 0.911 (1+t)$ and $\beta = 1.041 (1-t)$.

In these formula, $\rho_1 = D_1/D_e$ is the isophotal diameter D_1 expressed in units of the effective diameter D_e. The variation of ρ_{25} with T, and therefore of $K_D(25)$ and $(\partial K_D/\partial B)_{25}$ with T, is given in Table 2, from values of D_e, A_e, D_{25}, R_{25} and T coming mainly from the RC2 (for details see Fouqué 1982). The variation of K_D with T is shown in Fig. 5. A linear least-square fit of these data gives the following results:

- for elliptical and lenticular galaxies, K_D decreases linearly with type T, following (after rejection of $T=-4$ defined by too few points)

$$K_D(25) = 0.081 - 0.016\, T \quad (9a)$$

- for spiral galaxies, K_D has a constant value of:

$$K_D(25) = 0.094 . \quad (9b)$$

This invalidates the adopted law of RC2, which gives a constant decrease from elliptical to magellanic galaxies, according to:

$$K_D(\mathrm{RC2}) = 0.12 - 0.007\, T$$

also represented in Fig. 5.

An uncertainty is still remaining in our results for very late spiral galaxies. This comes from the fact that we adopt a pure exponential law for $T=5$ to $T=10$ morphological types. This point will further be investigated in Sects. 2.3 and 3 about LSB galaxies.

Table 2. Determination of $K_D(25)$ as a function of morphological type

Type (1)	N (2)	$\log \rho(25)$ (3)	$K_D(25)$ (4)	$-(\partial K_D/\partial B)_{25}$ (5)
−5	124	0.451	0.161	0.0149
−4	7	0.376	0.157	0.0208
−3	52	0.508	0.128	0.0193
−2	64	0.542	0.111	0.0174
−1	26	0.567	0.098	0.0156
0	25	0.508	0.100	0.0174
1	32	0.510	0.093	0.0163
2	33	0.486	0.092	0.0170
3	64	0.456	0.092	0.0178
4	70	0.421	0.095	0.0200
5	65	0.406	0.094	0.0202
6	35	0.398	(0.094)	(0.0202)
7	23	0.350	(0.094)	(0.0202)
8	18	0.298	(0.094)	(0.0202)
9	54	0.291	(0.094)	(0.0202)
10	86	0.249	(0.094)	(0.0202)

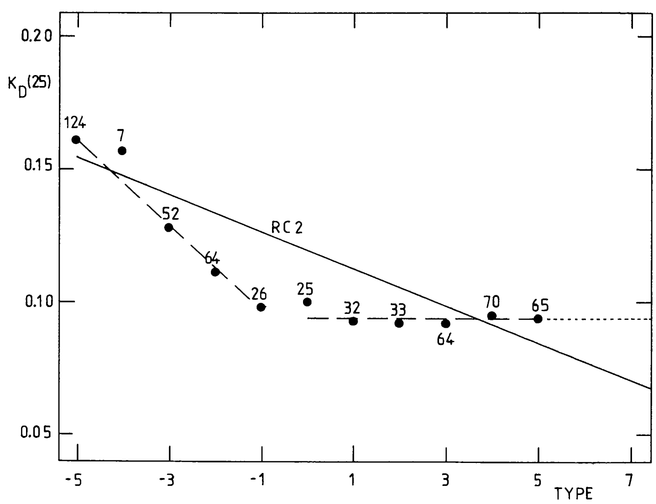

Fig. 5. Variation of $K_D(25)$ vs. the morphological type. The number of galaxies used is given for each experimental determination. The first approximation used in the RC2 is superimposed (solid line)

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It is difficult at present to study the variation with morphological type of the derivatives of $K_D(25)$. In fact, $(\partial K_D/\partial B)_{25}$ seems more or less constant with values in the range −0.020 to −0.015. Therefore, in a comparison of $D_{26.5}$ with D_{25} (i.e. $B_1 - B_{25} = 1.5$), the ratio between the second order term and the first order one is about 10%. Our conclusion is that the Taylor series converges only slowly, and we will use the development till the second order for comparison between $D_{26.5}$ and D_{25}, and at first order for comparison between catalogues and D_{25}, because the limiting surface brightness of the visual catalogues we are studying is known to be close enough to 25 mag arcsec^{-2}. But $|B_1 - B_{25}| = 1.5$ seems to be a maximum value for using this development and de Vaucouleurs and collaborators (RC2) were justified when not correcting Holmberg diameters to the D_{25} system because of too great extrapolation.

2.3. Application to photometric systems other than the standard one

From the previous analysis, we will study here three true photometric systems:
- the $D_{26.5}$ measurements of our standard catalogue (Fouqué and Paturel, 1983), in order to verify our values of $K_D(25)$.
- the $D_{26.6}$ measurements of LSB galaxies from Romanishin et al. (1983), in order to derive a value of $K_D(25)$ for this special class of galaxies.
- the D_{26} measurements in *V band* of Watanabe (1983), in order to compare preliminary measurements at different wavelengths.

As shown in the previous section, we can limit the Taylor formula to the 2nd order. Moreover, in order to improve our statistical basis, we will group galaxies in three classes of morphological types: ellipticals ($-6 \leqq T \leqq -4$); lenticulars ($-3 \leqq T \leqq -1$) and spirals ($0 \leqq T \leqq 10$). In Table 3, we show the results according to our relation (3), compared to the experimental fits. Some comments can be drawn from this table.
- for the $D_{26.5}$ standard measurements, we note a remarkable agreement for spiral galaxies between predicted and observed values of log $D_{26.5}/D_{25}$, which validates definitively our value of $K_D(25)$ for spiral galaxies, at least for $T \leqq 5$. For the lenticular and elliptical galaxies, too few points prevent us from concluding anything of the rather good agreement.

Table 3. Predicted and observed diameter ratios $\log(D_i/D_{25}(\mathrm{STD}))$ from different systems of diameters D_i, at different limiting surface brightness and different passbands: (1) STD: Standard 26.5 mag arcsec^{-2} in *B*-band. (2) WAT: Watanabe measurements at 26 mag arcsec^{-2} in *V*-band. (3) LSB: Romanishin LSB galaxies at 26.6 mag arcsec^{-2} in *B*-band

System	Type	Predicted ratio	Observed ratio	σ	N
STD	*E*	0.225	0.187 ± 0.022	0.082	14
	L	0.147	0.166 ± 0.014	0.061	19
	S	0.118	0.116 ± 0.009	0.051	35[a]
WAT	*E*	0.154	0.206 ± 0.016	0.067	17
	L	0.102	0.112 ± 0.011	0.060	32
	S	0.084	0.079 ± 0.013	0.049	14
LSB	*S*	0.124	0.171 ± 0.011	0.043	16

[a] NGC 4568 rejected at 2.9σ

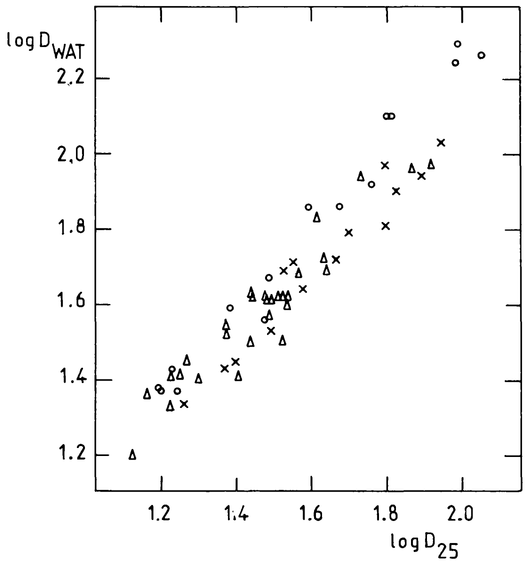

Fig. 6. Relation between Watanabe's diameters (at the 26 mag arcsec^{-2} in the *V*-band) and our standard D_{25} diameters in the *B*-band. The symbols represent different morphological types: circles: elliptical galaxies; triangles: lenticular galaxies; crosses: spiral galaxies. As expected, a morphological type effect is visible

- for the LSB galaxies, we obtain a value of log $D_{26.5}/D_{25}$ significantly larger than expected. We cannot extract from it a firm value of $K_D(25)$ for LSB, because $(\partial K_D/\partial B)_{25}$ is also unknown for LSB galaxies. From reasonable values of the latter quantity, we can estimate:

$K_D(25) = 0.12$ for LSB galaxies.

We cannot find presently the exact origin for such a high value because of our rather simple modelling for derivation of K_D.
- for Watanabe *V*-band D_{WAT} measurements, we have plotted Fig. 6 from which it is evident that elliptical galaxies (circle symbols) are above lenticulars (triangles), which are above spirals (crosses). This can be due to different photometric bands or to the $K_D(25)$ values greater for ellipticals than for lenticulars than for spirals. Table 3 shows that the main effect is the K_D effect. But there remains a slight tendency to have values for ellipticals larger than expected. This is a well known effect in the Nilson catalogue between red and blue diameters: for elliptical galaxies, the red diameter is larger than the blue one, while they are almost equal for spiral galaxies. The important result of our study is that this effect is secondary compared to the K_D effect. On another hand, the dispersion of results for Fig. 6 is of the same order than in the comparison of standard diameters at 26.5 and 25 mag arcsec^{-2} level. This shows the good quality of these japanese measurements and announce a promising comparison in the *B*-band.

3. Mean limiting surface brightness of the visual catalogues

Knowing the way to transform a visual measurement of galaxy diameter into a photometric system (addition of a 0.′3 constant to the measurement), we now must know the level of this system, in order to finally convert it to our standard photometric system, at the 25 mag arcsec^{-2} level. The way of working is the following: if D is the visual measurement of the diameter of a galaxy, we

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first add the constant $C = 0\rlap{.}'3$ to this diameter, in order to put it in a photometric system. We then compare this reduced diameter to the D_{25} and $D_{26.5}$ values for this galaxy in order to deduce from a linear interpolation the B_1 value for this galaxy. The mean limiting surface brightness of a catalogue is the mean of all the individual values of B_1 for galaxies in this catalogue. This procedure differs from the previous point of view of Paturel (1975a), for example, where the mean limiting surface brightness was just determined from the raw measurements. These previous determinations thus suffered from a bias, and it would be possible to show that different ranges of diameters lead to different determinations. Moreover, our additive constant will lead in the mean to larger values than those from Paturel (1975a). Therefore, we can hope to eliminate the slight difference reported by Paturel (1975) between the mean limiting surface brightness derived from minor axis diameters and from major axis diameters. This difference was about the same for the MCG and UGC catalogues, with a mean value:

$$\langle B(D) - B(d) \rangle = 0.17 \text{ mag arcsec}^{-2} .$$

Another effect outlined by Paturel (1975b) is the so-called "type effect". He found that for UGC, the mean limiting surface brightness increases with morphological type, but that there was no effect in MCG. In order to test this effect, we will share our sample as following:
- elliptical and lenticular galaxies: $-6 \leqq T \leqq -1$
- spiral and magellanic irregular galaxies: $0 \leqq T \leqq 10$
- LSB galaxies from Romanishin et al. (1983) with the addition of A1008-04.

IO and peculiar galaxies, and galaxies with unknown morphological type are ignored. Various limits have been used in the literature to share the sample in types. We choose the natural limit between lenticulars and spirals because of the shape of the $K_D(25)$ vs. T relation and its importance in the conversion relations. This limit is the same as the one adopted in RC2. LSB galaxies are treated separately because of the conclusion of Romanishin et al. (1983) that they do not follow the same conversion relations as normal galaxies; in absence of more information we kept the $0\rlap{.}'3$ value for the additive constant. Furthermore, we will not study the ESO catalogue, because after division in subsamples, there are at best 5 galaxies to define the mean limiting surface brightness. This is not enough and we therefore postpone the study of the limiting surface brightness of this catalogue to later revision. This outlines the urgency of more photometric studies of southern galaxies. To our two remaining visual catalogues, MCG and UGC, we will add the RC2 one, in order to test how close it is to the assumed value of 25 mag arcsec^{-2}, and the Holmberg one, to verify the 26.6 mag arcsec^{-2} value of Heidmann et al. (1972). The results are given in Table 4 and need some comments.
- the mean difference between $B(D)$ and $B(d)$, for UGC and MCG catalogues is now unsignificant, so this effect is well corrected.
- the type effect is only significant for UGC measurements. This confirms Paturel's results. The mean difference between $B(T \geqq 0)$ and $B(T < 0)$ is

$$\langle B(T \geqq 0) - B(T < 0) \rangle = 0.5 \text{ mag arcsec}^{-2}$$

where we have taken the mean of the results for major axis measurements and minor axis ones.
- the LSB galaxies have clearly mean limiting surface brightness greater than the one of normal galaxies. The mean difference is about the same for MCG and UGC measurements, with a mean value

$$\langle B(\text{LSB}) - B(T \geqq 0) \rangle = 0.8 \text{ mag arcsec}^{-2}$$

- the RC2 measurements are remarkably close to the 25 mag arcsec^{-2} level, with a mean value for all morphological types and for major and minor axis measurements (excluding the LSB galaxies):

$$\langle B(\text{RC2}) \rangle = 25.04 \pm 0.04 \text{ mag arcsec}^{-2}$$

- the Holmberg measurements (not corrected by any constant, according to de Vaucouleurs's precepts 1959) give:

$$\langle B(\text{HOL}) \rangle = 26.7 \pm 0.1 \text{ mag arcsec}^{-2}$$

in agreement with the previous determination by Heidmann et al. (1972).

Table 4. Mean limiting surface brightnesses for different systems of diameters. The limiting surface brightness and its mean error are given on line *a*. The standard deviation is given on line *b* together with the number of points (between brackets)

	RC2	UGC	MCG	HOL
Major axes				
$T \geqq 0$, non LSB	25.01 ± 0.05	25.70 ± 0.12	24.59 ± 0.16	26.66 ± 0.16
	0.31 (32)[a]	0.66 (29)	0.85 (27)	0.75 (21)
$T \geqq 0$, LSB	25.45 ± 0.13	26.53 ± 0.12	25.45 ± 0.15	27.20 ± 0.10
	0.46 (12)	0.44 (13)	0.61 (16)	0.23 (5)[b]
$T < 0$	25.07 ± 0.10	25.14 ± 0.10	24.64 ± 0.18	26.20 ± 0.25
	0.53 (30)	0.53 (27)[c]	0.66 (14)	0.70 (8)
Minor axes				
$T \geqq 0$, non LSB	25.12 ± 0.09	25.78 ± 0.13	24.40 ± 0.19	26.98 ± 0.19
	0.51 (33)	0.68 (28)[d]	0.95 (26)	0.86 (21)
$T < 0$	25.00 ± 0.12	25.43 ± 0.14	24.67 ± 0.15	26.83 ± 0.39
	0.66 (28)	0.72 (26)	0.53 (12)[e]	1.11 (8)

[a] NGC 3389 rejected at 3.0σ. [b] UGC 4841 rejected at 2.0σ. [c] NGC 4472 rejected at 2.8σ. [d] NGC 3898 rejected at 2.7σ. [e] NGC 4754 rejected at 2.7σ

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4. Conversion relations for diameters

Here is the main purpose of our paper. According to our scheme, we will first derive experimental relations by fitting the relation (2) with the appropriate constant to our measurements, thus obtaining a and b, and then compare these values with what we expect from our empirical statements of Sects 2 and 3.

4.1. Experimental results

Let us talk about our method of regression: we have used the results of the maximum likelihood method to fit a linear regression in our measurements, knowing one of the error, namely the one of our standard system D_{25}, which has been taken equal to 0.03 on $\log D_{25}$ (see Paper I). To verify the results of this method, we proceeded according to the following scheme:
- let $D_1 = D_i + C$, where $C = 0\farcm3$ for ESO, MCG and UGC catalogues and 0 for RC2 and standard diameters
- we share our sample between $T<0$ and $T \geqq 0$
- for each subsample, we fit the relation:

$$\log D_1 = a_1 \log D_{25} + b_1$$

with $\sigma(\log D_{25}) = \sigma_{X.1} = 0.03$. This gives a_1, b_1 and $\sigma_{Y.1}$
- we fit now in the opposite sense:

$$\log D_{25} = a_2 \log D_1 + b_2$$

using for $\sigma_{X.2}$ the previous value $\sigma_{Y.1}$. The obtained value $\sigma_{Y.2}$ generally differs from 0.03, but only very slightly; this is our verification.
- we fit again with slightly different $\sigma_{X.2}$ in order to obtain exactly $\sigma_{Y.2} = 0.03$. This gives the searched a and b values. The last $\sigma_{X.2}$ is the "σ of the catalog" (noted σ_{CAT}).
- rejections of aberrant points are made at the first step, the level of rejection depending on the number of points, in such a way that the probability of wrong rejection is 10%. Although this probability is rather severe, no rejection is needed. It was also verified that ESO measurements do not show an appreciable "time effect".

The adopted results for each subsample in morphological types and each catalogue are given in Table 5a, with the values of C (adopted constant), a (slope) and b (intercept), σ_{CAT} (mean error of each catalogue) and N (number of measurements). Diameters are always in $0\farcm1$ unit to be consistent with the RC2 values. We will now give some general remarks about these results, before the detailed analysis of the next section.
- results for $T<0$ are always less accurate than those for $T \geqq 0$, due to the more difficult visual measurement (Nilson, 1973) but also to the fact that they are based on less points and that the $K_D(25)$ value varies for these morphological types. Due to this latter reason, the intercept of the relation varies, and only a problem of size of the sample prevented us from sharing between lenticulars and ellipticals, which would be more appropriate. So the relation is naturally expected more dispersed than for spirals. The results for ESO ($T<0$) are hardly significant because of the smallness of the sample.
- the relations for $T \geqq 0$ have been obtained after *a priori* rejection of M31 and M33, in order not to force the slope, and with exclusion of LSB galaxies.
- the results confirm the high homogeneity of the UGC measurements which seem somewhat better than ESO (note, however, the number of measurements); MCG measurements are confirmed worse. The apparent high quality of RC2 ($T \geqq 0$) is artificial because of many standard galaxies in common.
- about RC2, it can be said that for $T \geqq 0$, $D_{25} = D(\mathrm{RC2})$. For $T<0$, it seems not to be the case. Anyway, we do not recommend to convert RC2 values to the D_{25} standard system, but rather to convert individual measurements from ESO, MCG and UGC and then to derive the weighted mean value (see below for weights)
- note that results in Table 5 do not apply to LSB galaxies.

Table 5. Adopted relations for conversion to the standard system at the 25 mag arcsec^{-2} (Paper I). The coefficients a and b are given with their mean error; σ is the dispersion in the catalogue in 5a (σ_{CAT}) and the standard deviation in 5b (σ); N is the number of points

5a. Major axis diameters (D in $0\farcm1$ unit).
$\log D_{25} = a \log(D_i + C) + b$

	RC2	UGC	MCG	ESO
C (in $0\farcm1$)	0	3	3	3
a ($T \geqq 0$)	1.003	0.983	1.020	0.998
m.e.	0.009	0.011	0.012	0.013
b ($T \geqq 0$)	−0.010	−0.034	−0.027	−0.130
m.e.	0.015	0.019	0.019	0.025
σ_{CAT} ($T \geqq 0$)	0.039	0.051	0.069	0.059
N	130	84	85	47
a ($T<0$)	1.085	1.105	1.070	0.896
m.e.	0.014	0.015	0.024	0.028
b ($T<0$)	−0.132	−0.165	−0.046	0.048
m.e.	0.021	0.023	0.036	0.046
σ_{CAT} (T<0)	0.061	0.068	0.074	(0.146)
N	91	76	38	13

5b. Axis ratios ($R_{25} = D_{25}/d_{25}$; D and d are respectively the major and minor axis diameters in $0\farcm1$ unit)
$\log R_{25} = a \log((D_i + C)/(d_i + C)) + b$

	RC2	UGC	MCG	ESO
C (in $0\farcm1$)	0	3	3	3
a ($T \geqq 0$)	1.086	1.011	0.949	1.204
m.e.	0.025	0.042	0.053	0.067
b ($T \geqq 0$)	−0.002	0.030	0.020	−0.018
m.e.	0.008	0.013	0.018	0.019
σ ($T \geqq 0$)	0.054	0.075	0.099	0.083
N	133	85	85	47
a ($T<0$)	0.952	1.029	1.004	1.128
m.e.	0.035	0.042	0.074	0.208
b ($T<0$)	0.004	0.016	0.018	0.047
m.e.	0.009	0.009	0.021	0.047
σ ($T<0$)	0.055	0.055	0.082	(0.127)
N	91	76	38	14

4.2. Comparison with "theory"

It is rather astonishing that for the three visual catalogues (ESO, MCG and UGC), the introduction of the $C = 0\farcm3$ constant leads

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to values of the slope very close to the expected value of 1 (for $T \geqq 0$). This is the confirmation of the necessity of introducing this constant and the confirmation that 0′.3 is the right value, in agreement with the Hubble (1932) measurements and the de Vaucouleurs (1959) results. In order to convince, we give the values of the slopes for $C=0$ and $C=1'.2$ for $T \geqq 0$

	UGC	MCG	ESO
$C=0$	0.920	0.940	0.954
$C=0'.3$	0.983	1.020	0.998
$C=1'.2$	1.157	1.240	1.121

The slope is extremely sensible to the value of C, but notice that ESO values are less sensible than the others. Notice also that for $C=1'.2$ the agreement between the catalogues is less good. In Figs. 7, 8 and 9 the ratio $(D_{UGC}+C)/D_{25}$ is plotted vs.

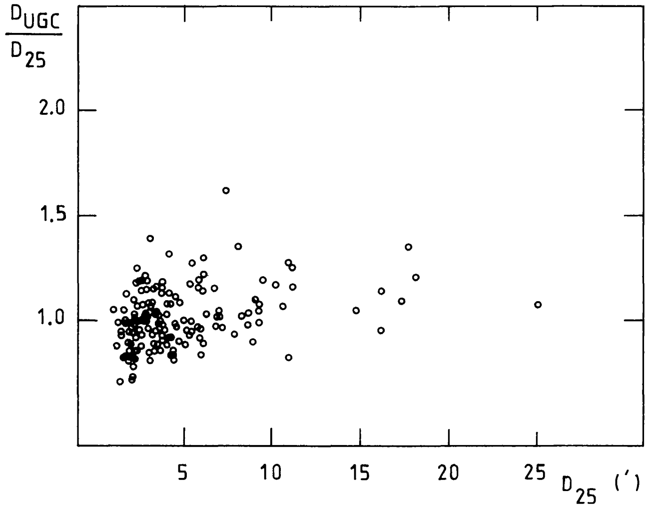

Fig. 7. Ratio D_{UGC}/D_{25} vs. D_{25}, where D_{25} is our standard diameter system. For $D_{25}<5'$ the ratio decreases, but is constant for $D_{25} \geqq 5'$

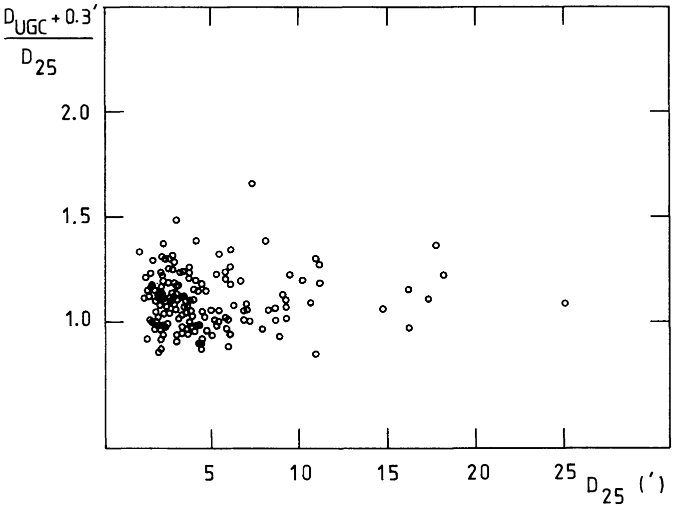

Fig. 8. Ratio $(D_{UGC}+0'.3)/D_{25}$ vs. D_{25}. The trend seen in Fig. 7 disappears, the ratio is constant for all D_{25} standard diameters. The 0′.3 correction transforms visual diameters into isophotal diameters (see text)

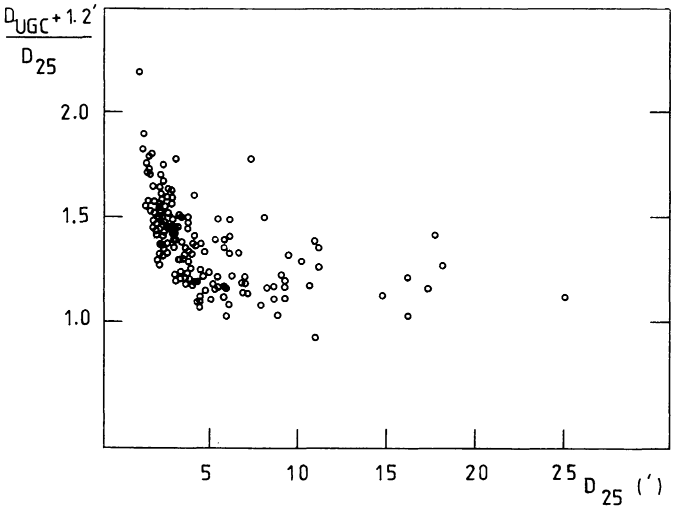

Fig. 9. Ratio $(D_{UGC}+1'.2)/D_{25}$ vs. D_{25}. The trend seen in Fig. 7 is overcorrected

D_{25} for the three values $C=0'$, $C=0'.3$ and $C=1'.2$ (as before, D_{25} denotes our standard system; the uncertain UGC measurement for NGC 4350 has been rejected). It is clearly visible that the value $C=0'.3$ well corrects the distortion, where the $C=0'$ shows a slight curvature towards the small diameters, and the $C=1'.2$ an evident overcorrection.

For $T<0$, it is difficult to conclude anything, because our predicted values are less valid, due to the reasons exposed in the previous section (less measurements and $K_D(25)$ variable). For this reason, and also to keep the precision of the experimental fits, we will keep the results of Table 5, and not force the slope to 1 for $T \geqq 0$. If we had done that, we would have arrived to the de Vaucouleurs (1959) relation:

$$D_{25}=A(D_i+C) \quad \text{with } A=\text{dex}(b).$$

Now we have verified that (at least for $T \geqq 0$), we can go further to relate the intercept value with the mean limiting surface brightness, knowing K_D. Indeed we have in the first order approximation:

$$\log(D_i+C)=\log D_{25}+(B_i-25)K_D(25)$$

where B_i is the mean limiting surface brightness for the considered visual catalogue, after correction of the measured diameters. The B_i values are those given in Table 4. So the observed intercept corresponds to

$$b=(25-B_i)K_D(25) \tag{10}$$

if the observed slope is 1. Comparison of the two quantities in relation (10) is made only for $T \geqq 0$. Indeed, the observed slope differs from 1 for $T<0$, and $K_D(25)$ is variable. $K_D(25)=0.094$ for $T \geqq 0$ and B_i is the value for major axis measurements, LSB galaxies being excluded. The mean result for UGC and MCG measurements is

$$\langle b-(25-B_i)K_D(25)\rangle=-0.01 \pm 0.02$$

where the errors are just taken on b and B_i, not on $K_D(25)$. The result is not significantly different from 0, but it is difficult to go further. We may nevertheless conclude that our rather simple "theory" is well confirmed by the experimental results and gives us confidence in our new conversion relations.

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4.3. Weights of the various measurements

Our philosophy is the same as in RC2: standard measurements are better than catalogue ones, but not enough to prevent us from taking the mean of the corrected and converted visual measurements with the standard ones. This compels us to evaluate weights for these different measurements in order to take a significant mean. The weights are of course related to the so-called σ_{CAT} of the catalogue, given in Table 5. For the standard measurements, we have adopted $\sigma = 0.03$ for major axis diameter. Subtleties are employed in RC2, according to the quality of the visual measurement claimed by his author. We cannot test the validity of these subtleties (could RC2 do it?), but some remarks can be made: two types of uncertainties are introduced in UGC; the first one is applied to most of the early-type galaxies (E and SO) and noted with brackets; it corresponds to a basic difficulty in the measure of this kind of galaxies. The second one, noted with a colon, corresponds to uncertain measurements (e.g. for disturbed galaxies). In the ESO catalogue, there is just the notation ":" for uncertain measurements, and in MCG, nothing. On the other hand, standard photometric measurements for early-type galaxies are also more difficult than for spirals, and RC2 gives to these measurements a weight 1.5 times smaller than for spirals. Because we will never take a mean between measurements for $T<0$ and for $T \geqq 0$, our scales for both subsamples can be independent. Just the relation between weight and error must be calibrated between both, and we keep the RC2 value 1.5 (for the weight), thus 1.22 for the error. Now, we can use the relative weights of RC2, but independently for $T<0$ and $T \geqq 0$, without reducing the weight of UGC, because of its more detailed treatment of uncertainties. The adopted relative weights are given below

$T<0$:	Standard	$w=1$
	UGC (with or without brackets)	$w=1$
$T \geqq 0$:	Standard	$w=1$
	UGC (without brackets)	$w=1$
	UGC (with brackets)	$w=\frac{1}{2}$

and for both subsamples, a colon multiplies the relative weight by $\frac{1}{2}$ (ESO and UGC), two colons or a question mark by $\frac{1}{4}$ (UGC only).

Let us now determine the actual weights W_i of the different sources, i.e. the weights when the relative weight w is 1. They are of course related to the dispersion of measurements in the catalogue, called σ_{CAT} and given in Table 5. The relation has the following form:

$$\sigma_i (W_i)^{1/2} = \text{constant}.$$

Because of our separated treatment of $T<0$ and $T \geqq 0$, we will have different constants for both subsamples. We have chosen the same value 0.1 (for $T \geqq 0$) as the one used in RC2.

$$\sigma_i (W_i)^{1/2} = 0.1 \quad \text{for } T \geqq 0$$

thus

$$\sigma_i (W_i)^{1/2} = 0.1(1.5)^{1/2} \quad \text{for } T<0.$$

Now our value for standards, $\sigma = 0.03$ is a mean over all morphological types. Taking into account the larger number of spirals entering in this mean, we arrive at the following weight for our standard measurements:

$W_{STD} = 13$ for all morphological types

For the catalogues, the results are:

	$T<0$	$T \geqq 0$
UGC	3.2 w	3.8 w
MCG	2.8	2.1
ESO	(2.8) w	2.8 w

where w is the relative weight for uncertain measurements defined just before. For the ESO $T<0$ very small sample, we have calculated σ_{CAT} by multiplying the value for $T \geqq 0$ by $(1.5)^{1/2}$, which seems to be a good measurement of the relative precision between measurements on $T<0$ galaxies and on $T \geqq 0$ ones; indeed the mean ratio $\sigma_{CAT}(T<0)/\sigma_{CAT}(T \geqq 0)$ is also 1.2 for UGC and MCG catalogues. So the calculated weight is the same as for $T \geqq 0$. The measured value for σ_{CAT}(ESO, $T<0$) has been discarded because clearly wrong, due to the smallness of the sample. The main difference in our results with RC2 is the greatly increased weight of the standard measurements. Also the values for MCG differ, with a better weight for $T<0$ and a worse for $T \geqq 0$, compared to RC2.

5. Conversion relations for axis ratio

First we have to justify our choice to convert axis ratios and not minor axis diameters, which are the measured quantities. This is due to the well-known effect that for nearly face-on galaxies, the converted minor axis diameter may be larger than the converted major axis diameter. We will see that this problem is not entirely eliminated when using the axis ratios, as often thought, and we will see how to solve this difficulty. Following the scheme for major axis diameters conversion, we will first derive the empirical relation of conversion, then look at the experimental results and finally discuss about the compatibility of our model with these results.

5.1. The empirical relation of conversion

The problem of converting axis ratios to a photometric standard system is far more complex than for diameters. Indeed, several perturbing effects can be noted, due to the fact that the measurement of the minor axis diameter is not independent of the measurement of the major axis diameter of the same galaxy. Two competing effects are present: first, a good one, coming from the fact that the measurements are taken at the same place on the same plate, so that all characteristics are the same: the quality of the plate, the limiting surface brightness, etc.... The second effect, the bad one, has different origins:

- for nearly face-on galaxies, people tend to give the same value to the diameters in both directions. It is for instance the case of Holmberg's measurements (see Heidmann et al., 1972)
- there is a discretisation of the values of the axis ratios, due to the rounded values of measurements of diameters. But for diameters, this effect is constant over the range, for example with measurements for each 0'.1. For axis ratios, it is particularly evident in UGC that round values of R (2, 5, 10) are preferred to adjacent ones.
- the shape of the outer parts of some galaxies is not always well elliptical, and extra-features perturb the measurement of good axis ratio, useful for deriving the inclination of the galaxy.

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Nevertheless, we can try to use our empirical model, described in Sect. 2, and look at the results to evaluate the importance of these perturbing effects. We know that we have first to correct the diameters to put them in a photometric system, in case of visual measurements. The first problem is to know whether the same correcting constant has to be applied to both diameters. Indeed, we can think that the non-independency of the measurements in both directions prevents us from applying the same additive constant. But we have seen in Sect. 3 that this procedure leads to mean limiting surface brightness for catalogues in agreement when measured along minor or major axis. So we apply it and we get a corrected axis ratio by:

$$R_1=(D_i+C)/(d_i+C) \tag{11}$$

where D_i and d_i are the major and minor axis diameters, and C is the additive constant (0.'3 for visual catalogues). We can see that this is not a linear correction. To our knowledge, it is the first time that axis ratios are corrected in this way.

Once this is done, we have to convert our "photometric" system at the B_1 level, to the standard level 25 mag arcsec^{-2}. This is done by formulas analogous to the relation (3), and limited to the first order:

$$\log D_1=\log D_{25}+(B_1-25)K_D(25)$$

$$\log d_1=\log d_{25}+(B_1-25)K_d(25)$$

where $K_d(25)=(\partial \log d/\partial B)_{25}$ and B_1 is the same for both relations.

$$\log R_1=\log R_{25}+(B_1-25)(K_D(25)-K_d(25))$$

$$\log R_1=\log R_{25}+(B_1-25)K_R(25) \tag{12}$$

where $K_R(25)=(\partial \log R/\partial B)_{25}$.

It is very difficult to study $K_R(25)$ directly, as we have done for $K_D(25)$. Paturel (1975b) derived, by a comparison between Holmberg and UGC measurements

$$K_d=0.34\log(D/d)+0.095$$

and said that the constant 0.095 could be interpreted as K_D. So we should have

$$K_R=K_D-K_d=-0.34\log R. \tag{13}$$

We can test these ideas by a direct comparison between our $R_{26.5}$ and R_{25} measurements. Indeed the relation (12) predicts for the regression $\log R_{26.5}$ vs. $\log R_{25}$ a slope 1 if K_R is independent of $\log R_{25}$ and $1-(1.5\times0.34)=0.49$ if the relation (13) is correct. We find

0.93 ± 0.05 for $T\geqq0$

1.04 ± 0.06 for $T<0$

which rules out the previous result by Paturel (rel. 13) and shows that $K_R(25)$ is nearly independent of R. This is probably due to an effect of morphological type because it is apparent from his results that K_R is different for $T<0$ ($K_R=0.01$) and $T\geqq0$ ($K_R=-0.05$). So every difference in the mean axis ratio of these two subsamples leads to an apparent dependence of K_R over R.

5.2. Experimental results

We cannot apply a sophisticated method of regression like for diameters, because we do not have an accurate value for the standard error on R_{25} measurements (see also Sect. 5.3.). We will fit a linear relation of the following form

$$\log R_{25}=a\log R_1+b \tag{14}$$

where $R_1=(D_i+C)/(d_i+C)$.

We adopt the mean regression (geometrical mean of the direct and inverse regressions). It is expected that the inverse regression (which corresponds to the hypothesis $\sigma(R_{25})=0$) is a little closer to the true regression. As expected, the inverse regression gives always errors larger than the direct one. The adopted errors are thus the ones of the inverse regression. As for diameters, we have shared the sample into $T<0$ and $T\geqq0$ subsamples. No rejection for aberrant points has been done, because of the generally large dispersions. The results are given in Table 5b, together with the results for diameters. A general remark must be done about the intercept of these relations: the converted axis ratio must be larger or equal to 1. So, the logarithm must be greater or equal to zero and thus also the intercept. In fact there are two exceptions, for RC2 and ESO ($T\geqq0$ for both). In both cases, the negative intercept is far from being significantly different from 0, and therefore, in the case of an axis ratio smaller than 1, we can adopt a value of 1.

It is to be noted that the results are always more dispersed than for major axis diameters; this reflects the problems evoked at the beginning of this section in the measure and conversion of axis ratios.

5.3. Comparison with the empirical relation and adopted results

The first point to verify is that for visual catalogues (UGC, MCG and ESO), the slope of the regression is nearly 1 (but not exactly 1, because we do not know the exact form of the variation of $K_R(25)$ with R). That is very well achieved, and confirms the probable result that $K_R(25)$ is nearly independent of R (see Sect. 5.1). But in one case, the ESO measurements for $T\geqq0$ galaxies, there is a significant departure from this result, probably not due to the small number of points, and unexplained. For $T<0$ galaxies in this catalogue, we have too few points to conclude anything, and for these reasons, axis ratios derived from ESO measurements and converted to our standard system must be regarded as less confident than for other catalogues. Although a slope of 1 is not expected for RC2 conversion, because this catalogue does not contain visual measurements, but means, it is alarming to see that for $T\geqq0$, we cannot write $R_{RC2}=R_{25}$, but that there is a systematic discrepancy. This correction, to be applied to RC2 value for axis ratios, is an a posteriori justification of our work, because most people are using RC2 values in the computation of inclinations of galaxies. The error in RC2 values is significant at a 99.9% level. Its origin is unclear.

In order to derive a final axis ratio, we have to take the mean of the various converted measurements. To weight this mean, we have to use the dispersion of measurements in each catalogue, and for standard measurements. Let us first evaluate this latter error. Two ways are possible. In Paper I, we have evaluated the mean errors for major axis measurements ($\sigma=0.027$ for the logarithm) and minor axis ones ($\sigma=0.035$). Combining these values, we have a first estimate of the mean error of a standard axis ratio value, if we admit that the measurements in the two directions are independent

$$\sigma(\log R_{25})=0.044. \tag{15}$$

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Let us consider now the other way. In order to get a rough estimate of the effect of the dependency of the measurements along major and minor axis on the error of log R_{25}, we can compare $\sigma(\log R)$ to $\sigma(\log D)$ for the different catalogues. The ratio is well in agreement for the three catalogues (for $T \geqq 0$) with a value of about $(2)^{1/2}$, indicating that the interdependency of the two measurements does not have a great influence over the error, because $\sigma(\log D)$ is nearly equal to $\sigma(\log d)$. So we adopt the result of relation (15). This is of the same order of magnitude as in RC2, and gives a mean error of 10% in the measurement of an axis ratio.

We have now to determine the weights to apply in the calculation of the mean value from standard and catalogue measurements. The relative weights w are the same as for major axis diameters (see Sect. 4.3). The distinction between the two types of uncertainties in UGC (brackets and colons) is here more important, because if the individual diameters of an elliptical are more difficult to measure than for a spiral, the axis ratio is best defined due to the more regular shape of isophotes. For this reason, we will not keep our different constants (constant $= \sigma_i(W_i)^{1/2}$) for $T<0$ and $T \geqq 0$, but choose the same value for both subsamples. Remembering the preceding remarks, this value will be (for all morphological types)

$$\sigma_i(W_i)^{1/2} = 0.1(2)^{1/2}. \quad (16)$$

Our non-distinction between both subsamples of morphological types is well supported by the results in Table 5, where, for diameters, $\sigma(T<0)$ is always greater than $\sigma(T \geqq 0)$; this is not the case for the axis ratios. Relations (15) and (16) define the weight of standard measurements as:

$W_{STD} = 10$ for all morphological types

and for the catalogues, the dispersions in Table 5 lead to:

	$T<0$	$T \geqq 0$
UGC	6.7 w	3.6 w
MCG	3.0	2.0
ESO	(2.9) w	2.9 w

where for ESO $T<0$ we have not relied on the observed dispersion because of too few points, but taken the results for $T \geqq 0$. Some particular remarks can be given in conclusion:

- Holmberg measurements are treated apart (next section), because of intrinsic problems: nearly face-on galaxies have $R=1$; measurements at different limiting surface brightness; results of Fig. 1....
- LSB galaxies are not treated, because the measurements by Romanishin et al. (1983) do not give axis ratios.
- one galaxy in UGC (UGC 942) has D and d inverted, giving a measured axis ratio less than 1. This must be corrected before conversion.
- except for UGC $T<0$ the weights are about the same as for major axis diameters, confirming the ratio $(2)^{1/2}$ between the errors on these quantities.
- comparison with the weights in RC2 shows the same trend in MCG as for diameters (better weight for $T<0$, worse for $T \geqq 0$) and an increased weight for UGC $T<0$, the reliability of which is not guaranteed.

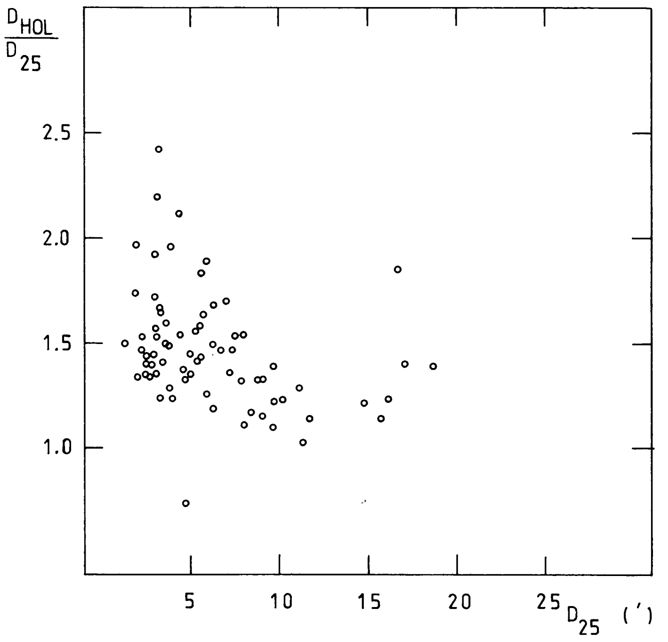

Fig. 10. Ratio D_{HOL}/D_{25} vs. D_{25}. The same trend as in Fig. 1 is present. This confirms that Holmberg's diameters do not constitute a system of isophotal diameters

6. The Holmberg catalogue case

Figure 7 has shown that the trend observed in Fig. 1 was probably due to the Holmberg measurements. Indeed, Fig. 10 proves it (the uncertain Holmberg value of the diameter for NGC 4567 has been rejected). Comparison with Fig. 11 allows to disentangle visually the effect of the trend due to the correlation of errors between abscissa and ordinate. Our following discussion rests

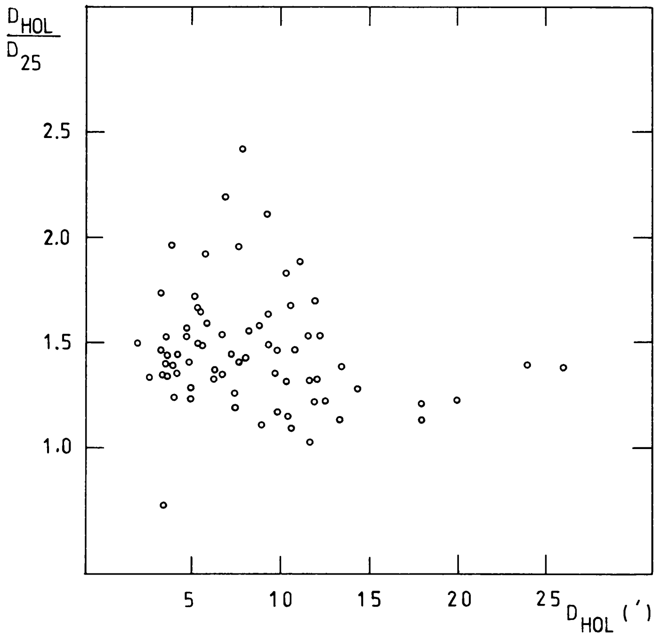

Fig. 11. Ratio D_{HOL}/D_{25} vs. D_{HOL}. This shows that the trend seen in Fig. 10 does not result from the interdependence of the quantities plotted on both axes

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on a "mean" diagram between Fig. 10 and Fig. 11. It is perhaps the first time that such an error is revealed in Holmberg's measurements, long thought to be free of biases and used as a standard system till the RC2 system of D_{25} diameters supersedes it. Holmberg (1958) himself claimed that his system was more or less isophotal.

An examination of Figs. 10 and 11 shows that two regions can be identified:
- for $D_{STD} \geqq 10'$, the ratio D_{HOL}/D_{STD} is nearly constant
- for $D_{STD} < 10'$, this ratio decreases with increasing D_{STD}, up to the constant value for $D_{STD} \geqq 10'$.

For the effect concerning large diameters, an explanation has been proposed by Burstein (private communication): large galaxies measured by Holmberg on plates taken with the 60 inches Mount-Wilson telescope have too small diameters, because the sky background was in fact measured in the outer regions of the galaxy, due to the size of the plates. Indeed, if we look at the 6 points in Fig. 11 with $D_{HOL} > 15'$, the five with small D_{HOL}/D_{STD} ratio are measured with the 60-inch telescope and the one with the largest ratio (NGC 5128) with the 48-inch telescope of Mount-Palomar.

Concerning now the trend at $D_{STD} < 10'$, we do not have any explanation, and thus we cannot propose a conversion formula to reduce these diameters to our standard system. Note that RC2 does not give a formula, because of the large difference of limiting surface brightness levels. Fouqué (1982), comparing RC2 and Holmberg's diameters, found what he called a "negative effect of diameter", which would correspond to a negative constant C in the formula 2. He found also that the magnitude of this effect (corresponding to the absolute value of C) was greater than for the visual catalogues. Indeed a constant $C = -2'.0$ would remove the trend in Fig. 10 (and thus in Fig. 1). But, (i) this large value of the constant is not justified on any physical ground, (ii) as can be seen from a comparison of Fig. 9 and Fig. 10, the dispersion is also increasing for decreasing diameters, in the case for Holmberg's diameters; this effect cannot be eliminated by simple addition of the constant C. We thus think that it is not the right way to reduce Holmberg's measurements to the standard system, and rest on the prudent position not to reduce these diameters.

For axis ratios, two effects will prevent us also to give a conversion formula to the standard system, as in RC2:
- the bias on diameters can produce a bias on axis ratios
- it is known (Heidmann et al., 1972) that several galaxies nearly face-on have then axis ratio exactly equal to 1 in the Holmberg catalogue. This biased ratio cannot be corrected. These galaxies are namely: NGC 628, 1156, 3631, 4214, 5457, 6822 and IC 1613 (but not NGC 4449 as said in Heidmann et al., 1972).

In conclusion, because of unexplained biases in the measures, we will not reduce the once-thought high quality Holmberg's measurements to our standard system, dropping thus 300 galaxies. This is not so important than before, because many of these galaxies are now well photometrically studied.

7. Conclusion

The importance of diameters of galaxies has often been neglected, when compared to magnitudes. For instance, it does not exist for diameters such a work as the series of papers by de Vaucouleurs and collaborators (Contributions to Galaxy Photometry, Papers I to IX: de Vaucouleurs, 1977a; de Vaucouleurs and Corwin, 1977; de Vaucouleurs et al., 1977; de Vaucouleurs and Bollinger, 1977a, b, c; de Vaucouleurs and Head, 1978; de Vaucouleurs and Pence, 1979a, b) defining a standard system of blue total magnitudes. But it must be kept in mind, for example, that single-aperture photometry requires an aperture correction to derive total magnitudes, which depends on the diameter. Reducing measurements from large catalogues gives us access to diameters for about 40,000 galaxies. This gives a large bulk of data for remote clusters, particularly important for the derivation of the Hubble constant, which would be long and difficult to measure photometrically. Improperly reduced diameters is perhaps the explanation of the effect noted by Kraan-Korteweg (1983), who finds different relations infra-red surface brightness −21 cm line width for different clusters. Application of our new system of diameters to the determination of the extragalactic distance scale is given in Tully and Fouqué (1985).

We have thus shown that, correcting visual diameters for a photovisual effect by an additive constant C, the value of which has been proved to be $0'.3$ in agreement with earlier determinations (Hubble, 1932; de Vaucouleurs, 1959), visual measurements can be converted to an isophotal system, which has been reduced for each catalogue to our standard system (Fouqué and Paturel, 1983, Paper I) at the 25 mag arcsec^{-2} level of limiting surface brightness. This new system is applied in Tully and Fouqué (1985) to reinvestigate the basic corrections to observables in the extragalactic distance scale, such as magnitudes and diameters, for aperture, absorption and projection effects. In this paper we show that all the problems are not resolved in the reduction of small diameters and that it is therefore important to make photometric measurements. In order to understand the remaining discrepancies for small galaxies, one of us (P.F.) is engaged in such a program, by means of CCD photometry. Another problem

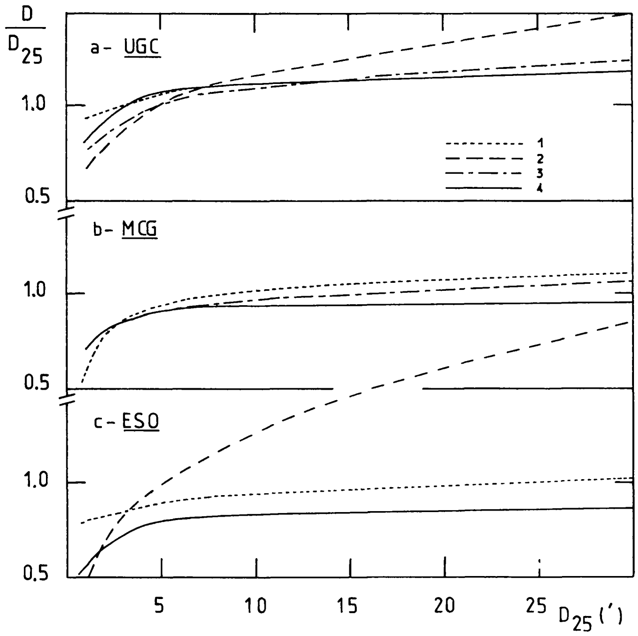

Fig. 12. Comparison between different relations for reducing visual diameters to the standard D_{25} system. a - for UGC diameters. b - for MCG diameters. c - for ESO diameters. The curves are coded as following: **a** 1: de Vaucouleurs et al. (RC2, 1976). 2: de Souza et al. (1984). 3: Paturel (1975b). 4: this paper (Table 5). **b** 1: RC2. 3: Paturel. 4: this paper. **c** 1: Lauberts (1982). 2: Mould and Ziebell (1982). 4: this paper. Only the use of a constant $C = 0'.3$ in relation (2) gives a rapid decrease for $D_{25} < 5'$ and a constant value for $D_{25} \geqq 5'$. Note that in Fig. 12b the RC2 relation corresponds to $C = 0'.3$

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concerns Holmberg's catalogue, in which we have found systematic errors in the measurements, which are waiting for an explanation. In consequence, we do not recommend the use of these diameters, or diameters statistically reduced to this system. Our standard system is proved to be free of systematic errors in Tully and Fouqué (1985).

We wish to terminate with a graphical comparison of some formulae of reduction that can be found in the literature (Paturel, 1975b; de Vaucouleurs et al. 1976; Lauberts, 1982; Mould and Ziebell, 1982; de Souza et al., 1984) with those obtained in this paper (Table 5). From each formula (for $T \geqq 0$) we calculate the ratio D/D_{25} and plot it vs. D_{25}. Figure 12 shows this ratio for visual diameters D (UGC, MCG and ESO respectively). This comparison will be used to justify one more time, the necessity of the C term in rel. 2.

Figure 7 has shown that for $D_{25} < 5'$ the ratio D/D_{25} rapidly decreases, while for $D_{25} > 5'$ this ratio is constant. When C is equal to zero and a (the slope) has a low value (e.g. de Souza et al.: $a = 0.84$; Mould and Ziebell: $a = 0.80$) the decrease at small diameters is strong enough, but the ratio does not remain constant at large diameters. This is clearly visible in Figs. 12a and 12c. On the contrary, when C is equal to zero and a has a high value (e.g. RC2 for UGC: $a = 0.92$; Lauberts for ESO: $a = 0.96$) the ratio is quite constant for large diameters, but the decrease is not strong enough for small diameters. The use of a value $C = 0\overset{'}{.}3$ gives a rapid decrease for small diameters without increasing the ratio at large diameters.

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