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# Total Magnitudes of Virgo Galaxies. I. Construction of a Self-Consistent Reference Dataset Spanning 8th to 18th Magnitude

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**Abstract:** The main objectives of this series of papers are: (1) to demonstrate the existence of serious mutual disagreements between established total (and other integrated) magnitude scales for Virgo galaxies; (2) to attempt to quantify both the systematic and random errors present within these magnitude scales; (3) to investigate the origins of any large error uncovered; and thereby (4) to encourage the general adoption of rigorous total-magnitude measurement procedures by the astronomical community. The ramifications of the findings presented in this series of papers will be discussed in detail at a later date.

In this paper, the first in the series, a self-consistent dataset of trustworthy total-magnitude measurements is compiled for a sample of Virgo galaxies spanning a range of 10 000 in apparent brightness, based on only the most reliable measurements and photometry currently available. This reference dataset, which includes luminosity profile shape information, will be used in subsequent papers as one of the bases for assessing existing magnitude scales for Virgo galaxies. As most published magnitudes are based on *B*-band observations, this series of papers will also focus primarily on *B*-band measurements.

**Keywords:** catalogues — galaxies: clusters: individual (Virgo) — galaxies: fundamental parameters — galaxies: photometry — methods: data analysis — techniques: photometric

## 1 Introduction

Although galaxy total magnitudes are required for a large number of astronomical applications, they are notoriously difficult to estimate accurately or even consistently. There are a very large number of reasons for this unfortunate state of affairs.

One major problem is that atmospheric seeing effects can distort the luminosity profiles of galaxies very significantly. Under such conditions, profile extrapolation based on standard growth curves generally leads to spurious results, as demonstrated by Young et al. (1998). This problem is of course most acute when dealing with very distant galaxies and/or observations made under poor seeing conditions.

Another serious problem is that it is often technically difficult (or at least impractical) to determine reliably the luminosity profiles of many galaxies out to large enough radial distances so as to be able to avoid large extrapolations. The situation is of course most adverse when dealing with very low surface brightness objects for which very deep photometry is really essential.

By contrast, one of the greatest difficulties to be overcome in the CCD photometry of bright galaxies is how to determine the level of the sky accurately, when the target galaxies are often large enough to fill entire CCD

frames. Although wide-field photographic photometry does not suffer from this hazard, photographic emulsions are deficient in terms of their dynamic ranges. In order to prevent the saturation of photographic emulsions, only short-exposure or ‘shallow’ photographic photometry is therefore possible for bright galaxies.

In the case of the Virgo direction, the sheer diversity of objects we are confronted with poses what may well be the ultimate challenge to anyone trying to construct a self-consistent and reliable total-magnitude scale. Not only do cluster members systematically catalogued to date span an apparent brightness range of 8th–18th magnitude, but a full complement of different morphological types is present too. Furthermore, on account of the relatively loose clustering of member galaxies and Virgo’s uniquely large angular extent on the sky, background galaxies begin to dominate the galaxy number counts at 16th magnitude.

In this paper, we isolate several sources of total-magnitude measurements and photometry for Virgo galaxies that we have good reason to believe are reliable. In some cases, we are able to adopt the published magnitude measurements without modification, whilst in other cases, it was necessary to derive new total-magnitude values based on existing photometry. Papers II, III and IV will deal with the magnitude scales of the *Catalogues of*

**Table 1.** VPC objects for which alternative  $B'_t = U_t - (U - B)$  values (bold type) could be derived from a combination of VPC  $U_t$  values and non-VPC  $(U - B)$  colours based on aperture photometry measurements

| Designation<br>VPC/other | type | $U_t$<br>(mag.) | $U_{25} - U_t$<br>(mag.) | $(U - B)$<br>(mag.) | $\sigma_{(U-B)}$<br>(mag.) | aperture<br>(arcsec) | $(U - B)$<br>source | $B'_t$<br>(mag.) | $B_t$<br>(mag.) | $B_{J25} - B_{Jt}$<br>(mag.) |
|--------------------------|------|-----------------|--------------------------|---------------------|----------------------------|----------------------|---------------------|------------------|-----------------|------------------------------|
| 35/VCC 334               | dI   | 15.99           | 0.16                     | -0.21               | 0.04                       | 19.0                 | GH                  | <b>16.20</b>     | 16.49           | 0.25                         |
| 256/IC 3239              | dI   | 16.32           | 0.12                     | -0.28               | 0.05                       | 40.0                 | GH                  | <b>16.60</b>     | 16.47           | 0.22                         |
| 342/VCC 729              | dE   | 15.77           | 0.25                     | 0.10                | 0.04                       | 35.6                 | NC                  | <b>15.67</b>     | 15.78           | 0.38                         |
| 408/VCC 793              | dI   | 17.14           | 0.28                     | -0.02               | 0.08                       | 19.0                 | GH                  | <b>17.16</b>     | 17.17           | 0.50                         |
| 420/VCC 810              | dE   | 17.18           | 0.69                     | 0.27                | 0.10                       | 35.6                 | NC                  | <b>16.91</b>     | 17.12           | 0.69                         |
| 502/IC 3355              | dI   | 15.74           | 0.14                     | -0.20               | 0.04                       | 60.0                 | GH                  | <b>15.94</b>     | 15.35           | 0.34                         |
| 670/IC 3416              | dI   | 15.37           | 0.25                     | -0.19               | 0.05                       | 19.0                 | GH                  | <b>15.56</b>     | 15.51           | 0.24                         |
| 801/VCC 1348             | dE   | 15.72           | 0.73                     | 0.34                | 0.05                       | 39.0                 | NC                  | <b>15.38</b>     | 15.66           | 0.57                         |
| 808/VCC 1352             | dE   | 17.81           | 0.85                     | 0.12                | 0.15                       | 39.0                 | NC                  | <b>17.69</b>     | 17.60           | 0.66                         |
| 829/VCC 1377             | dI   | 16.61           | 1.23                     | 0.11                | 0.11                       | 40.0                 | GH                  | <b>16.50</b>     | 16.11           | 0.87                         |
| 834/VCC 1386             | dE   | 15.69           | 0.48                     | 0.19                | 0.05                       | 35.6                 | NC                  | <b>15.50</b>     | 15.26           | 0.52                         |
| 835/VCC 1389             | dE   | 16.65           | 0.42                     | 0.21                | 0.08                       | 35.6                 | NC                  | <b>16.44</b>     | 16.61           | 0.38                         |
| 843/VCC 1407             | dE   | 15.83           | 0.25                     | 0.26                | 0.04                       | 35.6                 | NC                  | <b>15.57</b>     | 15.61           | 0.40                         |
| 856/VCC 1420             | dE   | 17.47           | 0.40                     | 0.24                | 0.08                       | 35.6                 | NC                  | <b>17.23</b>     | 16.95           | 0.36                         |
| 897/IC 3483              | dI   | 15.22           | 0.28                     | 0.04                | 0.04                       | 19.0                 | GH                  | <b>15.18</b>     | 15.08           | 0.47                         |
| 937/VCC 1539             | dE   | 16.60           | 0.66                     | 0.15                | 0.09                       | 35.6                 | NC                  | <b>16.45</b>     | 15.92           | 0.76                         |

Notes: (1) The sources of  $(U - B)$  aperture photometry measurements are NC: Caldwell (1983) and GH: Gallagher & Hunter (1986). Except for  $B'_t$ , the other quantities are from the VPC. (2) The extrapolation terms  $U_{25} - U_t$  and  $B_{J25} - B_{Jt}$  are the bases of the error budgets shown in Figure 1. (3) The new  $B'_t$  values are probably less accurate for galaxies of type dI than for objects of type dE, as the former are more likely to possess significant colour gradients.

*Galaxies and of Clusters of Galaxies* (Volume I: Zwicky, Herzog & Wild 1961; Volume II: Zwicky & Herzog 1963), the *Reference Catalogues of Bright Galaxies* (RC2: de Vaucouleurs, de Vaucouleurs & Corwin 1976; RC3: de Vaucouleurs et al. 1991), and the *Virgo Cluster Catalog* (VCC: Binggeli, Sandage & Tammann 1985) respectively, whilst further papers in the series will deal with the magnitude scales of smaller datasets.

## 2 Faint Galaxy Sample (18th–14th magnitude)

At present, the most reliable source of blue total magnitudes for large numbers of faint Virgo galaxies is Young & Currie's (1998a) *Virgo Photometry Catalogue* (VPC), which presents  $U$ ,  $B_J$  and  $R_C$  photographic photometry for over one thousand galaxies in the direction of the Virgo Cluster's core. Curiously, the VPC is actually the first independently calibrated general catalogue of galaxies to cover Virgo since Volumes I (Zwicky et al. 1961) and II (Zwicky & Herzog 1963) of the *Catalogue of Galaxies and of Clusters of Galaxies*. It is based on numerically integrated plate-scan data obtained from UK Schmidt plates using the Royal Observatory Edinburgh's *COSMOS* microdensitometer. All total magnitudes listed in the VPC are derived according to the  $t$  system of Young et al. (1998).

Unfortunately, the VPC does not present  $B_J$ -band photometry for any galaxy brighter than 14th magnitude, on account of saturation effects. As its  $B$ -band total magnitudes are transformed values based on the original  $B_J$ -band values and  $B_J - R_C$  colours, the VPC lists  $B$ -band values only for objects for which  $B_J - R_C$  colours could be obtained and whose  $B_J$ -band photometry was

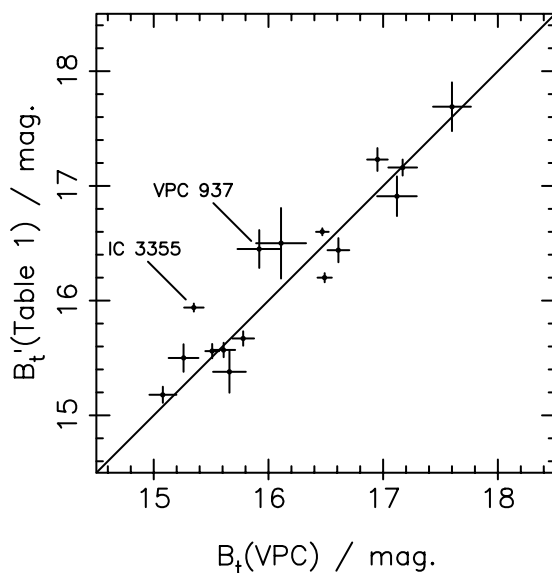
unsaturated. Comparisons between the VPC's  $B_t$  magnitude scale and the total-magnitude scales of other works, specifically Young (1994; 1997) and Young & Currie (1998b), have therefore previously been restricted to faint Virgo galaxies exclusively. However, as the VPC's  $U$ -band photometry was slightly shallower than its  $B_J$ -band photometry, there are actually 48 objects for which new  $U$ -band photometry is presented in the VPC, even though their  $B_J$ -band surface brightness profiles are saturated.

In order to investigate the possibility of extrapolating the VPC's  $B_t$  magnitude scale brightward of 15th magnitude by combining  $U_t$  values from the VPC with published  $(U - B)$  measurements from other sources, a literature search was conducted for  $(U - B)$  measurements of faint Virgo galaxies. It was found that Caldwell (1983) and Gallagher & Hunter (1986) had observed a total of 16 objects for which the VPC quotes new  $B_t$  values. These objects are listed in Table 1. A comparison was then made between the  $B_t$  values quoted in the VPC and alternative  $B'_t = U_t - (U - B)$  values (Table 2). The mean  $B'_t - B_t$  offset between the two sets of values was found to be only  $+0.08(\pm 0.07)$  magnitude. From Figure 1, there is no evidence for any scale error either, and the mean offset collapses to  $+0.01(\pm 0.05)$  magnitude if the two outliers, IC 3355 and VPC 937 (=VCC 1539), are excluded. As the  $(U - B)$  aperture photometry measurements are susceptible to errors arising from colour gradients (when present) not being taken into account and/or centering problems, particularly when small apertures are used, the  $B'_t$  values are probably on average of similar accuracy to the VPC's  $B_t$  values (for which transformation from  $B_J$  was necessary). They can however, only be derived for a small number of objects on account of the scarcity of published

**Table 2.** New  $B_t = U_t - (U - B)$  estimates (**bold type**) for galaxies with published  $(U - B)$  colours for which the VPC's photometry was saturated in  $B_J$  but unsaturated in  $U$ 

| Designation<br>VPC/other | VCC type/<br>membership | $U_t$<br>(mag.) | $U_{25} - U_t$<br>(mag.) | $(U - B)$<br>(mag.) | $\sigma_{(U-B)}$<br>(mag.) | aperture<br>(arcsec) | $(U - B)$<br>source | $B_t$<br>(mag.) |
|--------------------------|-------------------------|-----------------|--------------------------|---------------------|----------------------------|----------------------|---------------------|-----------------|
| 178/NGC 4305             | Sa/M                    | 13.54           | 0.61                     | 0.30                | 0.1                        | 142.7                | SV96                | <b>13.24</b>    |
| 328/NGC 4352             | S0/M                    | 13.87           | 0.37                     | 0.39                | 0.03                       | 34.5                 | RC3e                | <b>13.48</b>    |
|                          |                         |                 |                          | 0.40                | 0.06                       | $\infty$             | RC3T                |                 |
| 532/NGC 4431             | dS0/M                   | 14.43           | 0.33                     | 0.43                | 0.07                       | $\infty$             | RC3T                | <b>14.00</b>    |
| 544/NGC 4436             | dE-dS0/M                | 14.49           | 0.38                     | 0.30                | 0.05                       | 40.6                 | RC3e                | <b>14.19</b>    |
|                          |                         |                 |                          | 0.29                | 0.07                       | $\infty$             | RC3T                |                 |
| 665/NGC 4468             | S0-Sa/M                 | 14.16           | 0.40                     | 0.33                | 0.1                        | 89.3                 | SV96                | <b>13.83</b>    |
|                          |                         |                 |                          | 0.34                | 0.02                       | 54.7                 | RC3e                |                 |
|                          |                         |                 |                          | 0.33                | 0.03                       | $\infty$             | RC3T                |                 |
| 778/NGC 4491             | SBa                     | 13.89           | 0.19                     | 0.25                | 0.1                        | 89.3                 | SV96                | <b>13.64</b>    |
| 820/NGC 4497             | SB0-SBa/M               | 13.79           | 0.23                     | 0.34                | 0.1                        | 89.3                 | SV96                |                 |
|                          |                         |                 |                          | 0.29                | 0.06                       | 62.8                 | RC3e                | <b>13.50</b>    |
|                          |                         |                 |                          | 0.25                | 0.06                       | $\infty$             | RC3T                |                 |
| 838/IC 797               | SBc/M                   | 13.83           | 0.11                     | -0.05               | 0.1                        | 89.3                 | SV96                | <b>13.88</b>    |
| 855/NGC 4506             | S(pec)/M                | 13.94           | 0.42                     | 0.23                | 0.1                        | 142.7                | SV96                | <b>13.71</b>    |
| 865/IC 3470              | dE/M                    | 15.18           | 0.21                     | 0.36                | 0.1                        | 32.0                 | WT73                | <b>14.82</b>    |
| 885/IC 3481              | E(pec)/B                | 14.54           | 0.86                     | 0.55                | 0.04                       | 25.6                 | RC3e                | <b>13.99</b>    |
|                          |                         |                 |                          | 0.51                | 0.04                       | $\infty$             | RC3T                |                 |
| 918/IC 3499              | E-S0/M                  | 14.74           | 0.17                     | 0.25                | 0.05                       | $\infty$             | RC3T                | <b>14.49</b>    |
| 948/NGC 4531             | Sa(pec)/M               | 12.90           | 0.26                     | 0.32                | 0.1                        | 142.7                | SV96                | <b>12.58</b>    |

Notes: (1) Membership assignments are based on radial velocities: M (for member) if less than  $3500 \text{ km s}^{-1}$ ; otherwise B (for background). (2) The sources of  $(U - B)$  measurements are: WT73 for Tift (1973); RC3 for de Vaucouleurs et al. (1991) (e for effective colour, T for total colour); and SV96 for Schröder & Visvanathan (1996). When the  $(U - B)$  values listed are simply those corresponding to the largest aperture quoted by a particular source,  $\sigma_{(U-B)}$  has been arbitrarily set to 0.1 magnitude (3) The quantity 'aperture' is strictly only applicable to the SV96 and WT73 measurements. In the case of the RC3e measurements, the quoted values are the effective diameters ( $A_e$ /arcsec in the notation of the RC3). Although the RC3T measurements are based on extrapolations to infinite radial distances, they may suffer from systematic errors as demonstrated by Young et al. (1998). The new  $B_t$  values are therefore only based on RC3T measurements when alternative measurements are unavailable. (4) In order to minimise possible errors due to colour gradients not being taken into account, the new  $B_t$  value for NGC 4468 was based on the aperture measurement made with the largest aperture. In the case of NGC 4497 however, owing to considerable scatter in the published  $(U - B)$  measurements, a median  $(U - B)$  value was adopted instead.



**Figure 1** A comparison between  $B_t$  values derived from the VPC's  $U$  and  $B_J$ -band photometry (see Table 1). The error bars only represent uncertainties in the extrapolation terms beyond the limiting  $U$  and  $B_J$  isophotes, and have been set to one quarter of the  $B_{J25} - B_t$  and  $U_{25} - U_t$  extrapolation terms (from Table 1) in magnitude. Datapoints represent individual galaxies and the equality line is shown for reference.

$(U - B)$  colours for faint objects. In the case of VPC 937, the cause of the 0.53 magnitude discrepancy between its  $B_t'$  and  $B_t$  is unclear. However, in the case of IC 3355, the 0.59 magnitude discrepancy may well be due to the proximity of several giant galaxies (see Section 8 of Young & Currie (1998a)).

### 3 Intermediate Galaxy Sample (14th–12th magnitude)

In the light of the high level of consistency found between  $B_t$  values derived from the VPC's  $U$  and  $B_J$ -band photometry for faint objects, another literature search was conducted for  $(U - B)$  colours for those 48 objects with unsaturated  $U$ -band but saturated  $B_J$ -band photometry. The apparent brightnesses of these galaxies lie within the range  $16.72 \geq U_t \geq 12.90$  magnitude. Those 13 objects for which colours could be found are listed in Table 2, together with newly derived  $B_t$  estimates for them.

### 4 Bright Galaxy Sample (14th–8th magnitude)

As already mentioned, existing CCD photometry of the brightest Virgo galaxies is generally susceptible to sky subtraction problems, whilst photographic emulsions are

of limited use because of their small dynamic range. One dataset that stands out from existing CCD and photographic ones is the ‘globally mapped’ surface photometry of Caon, Capaccioli & Rampazzo (1990) and Caon, Capaccioli & D’Onofrio (1994). This photometry couples wide-field photographic images, for which the sky can be determined accurately, with CCD images of the central parts of galaxies that are saturated on most photographic plates.

Caon et al. (1990) presented two different sets of total-magnitude estimates: those listed in their Table I and those listed in their Table VI. Each Table I value was obtained by means of an integration to the relevant limiting isophote followed by an  $r^{1/4}$  law extrapolation (based only on the outer few isophotes of each luminosity profile) to an infinite radial distance. Each Table VI value on the other hand, was obtained by integration only, but this time to a relatively large radial distance greater than that of the limiting isophote of the published photometry. This latter distance was set as the point at which the surface brightness of the galaxy would fall to  $\mu_B = 32 \text{ mag.arcsec}^{-2}$  if the  $r^{1/4}$  law extrapolation (used to generate its Table I value) were an accurate description of the unmeasurable outer parts of the galaxy profile. The total magnitudes presented by Caon et al. (1994) were derived in the same way as Caon et al.’s (1990) Table VI values.

With a view to generating self-consistent  $t$ -system magnitudes independent of any  $r^{1/4}$  law assumption, it was decided to derive new total-magnitude estimates from Caon et al.’s (1990; 1994) original surface brightness profiles. This was done by integrating the actual light curves numerically between the galaxy centroids  $r = 0$  and the faintest isophotes  $r = r_{\text{max}}$ , where  $r$  represents azimuthally averaged radial distance. In order to maximise the accuracy of these integrations, the profiles were interpolated in linear-distance–linear-intensity space (rather than  $r^{1/4}$  magnitude space in line with the units listed), and using Hill’s (1982) interpolation routine INTEP. Note that the surface brightness profiles of even the largest giants extended to large enough radial distances so as to include a substantial proportion of any halo light. The profile of NGC 4406 (=M86) for example, extended out to a radial distance of 10.4 arcmin.

We also re-fitted Caon et al.’s (1990; 1994) light curves with Davies et al.’s (1988) more natural form of Sérsic’s (1968) law, ignoring isophotes flagged as unreliable and/or lacking ellipticity values. This yielded new global profile parameters for each galaxy which were then used for the extrapolation of each profile beyond the limiting isophote to an infinite radial distance. In practice, this involved integrating the best fitting Sérsic (1968) model from  $r = 0$  to  $r = \infty$  analytically according to Equation 7 of Young et al. (1998), and also integrating the same model from  $r = 0$  to  $r = r_{\text{max}}$  numerically using Simpson’s rule. The extrapolation term required was therefore the difference between these two values. The improved total magnitude values together with all relevant profile parameters and extrapolation terms are listed in Table 3. Note

that we omitted NGC 4649 because Caon et al. (1990) noticed that its isophotes were distorted by the presence of a companion galaxy. Also, in the case of Caon et al.’s (1994) profiles, we only fitted those 16 Virgo objects listed in Table (a) of the machine readable version at the CDS.

## 5 Bright-end Consistency Checks

It is reassuring to find that for the three objects in common between Tables 2 and 3, the new total-magnitude values are in good agreement. For NGC 4352, NGC 4431, and NGC 4436, the differences (Table 2 minus Table 3) are  $-0.01$ ,  $+0.04$ , and  $+0.18$  magnitude respectively.

For bright Virgo galaxies, another dataset was identified as likely to be of the highest quality — that of Michard (1982) whose total magnitudes, which were derived from photoelectric aperture photometry measurements, have been adopted here without modification. Note however, that whilst we have excluded all objects whose photometry Michard (1982) flagged as unreliable, we have not excluded objects when his only concern was that the extrapolation terms were large. One aspect of Michard’s (1982) work that sets it apart from that of most other authors is that it took into account systematic departures from the standard growth curves relevant to each galaxy’s morphological type. This was done by applying the best fitting standard growth curve from the *Second Reference Catalogue of Bright Galaxies* (RC2) of de Vaucouleurs et al. (1976) in each case, not the one listed as appropriate to the galaxy’s morphological type. A list of the values adopted is given in Table 4.

As is evident from Figure 2, there is no evidence for any scale error between the new total magnitudes derived from Caon et al.’s (1990; 1994) original photometry and Michard’s (1982) values, provided one excludes the six bright objects for which the profile-shape parameter  $n$  was found to be less than 0.25. This would appear to confirm that zero-point differences between the photometry of Caon et al. (1990; 1994) and Michard (1982) are small.<sup>1</sup> Note that the error terms on Michard’s (1982) magnitudes are generally larger than those on our values due to larger extrapolation terms<sup>2</sup> and fewer measurements per luminosity profile.

Unfortunately there is only one object in common between Michard’s (1982) galaxy sample and those objects listed in Table 2, namely NGC 4468. As Michard (1982) flagged most of the aperture measurements for this galaxy as unreliable, it has not been listed in Table 4.

<sup>1</sup>Caon et al. (1990; 1994) have already quantified the photometric offsets with respect to Michard’s (1982) aperture photometry. These offsets are probably dominated by an off-centering bias effect and correspond to  $\mu_{\text{Caon}} = \mu_{\text{Michard}} - 0.17$  magnitude for the smallest ( $r = 11.8$  arcsec) aperture used by Michard (1982) and  $\mu_{\text{Caon}} = \mu_{\text{Michard}} + 0.07$  magnitude for the largest ( $r = 99.3$  arcsec) aperture used.

<sup>2</sup>By extrapolation terms we mean the  $B_{A_{\text{max}}} - B_T$  terms listed in Table 4 for Michard’s (1982) aperture photometry and the  $\Delta B$  terms listed in Table 3 for our magnitudes.

**Table 3. Improved total magnitude values (bold type) derived in this paper from a re-analysis of Caon et al.'s (1990; 1994) surface brightness profiles; the hitherto undefined quantities  $\epsilon$ ,  $\mu_{B_0}$ , and  $r_0$ , being ellipticity, Sérsic-model extrapolated central surface brightness and Sérsic-model scalelength respectively**

| Designation       | VCC type/<br>membership | $B_{r < r_{\max}}$<br>(mag.) | $r_{\max}$<br>(arcsec) | $\epsilon$ | $\mu_{B_0}$<br>(mag.arcsec $^{-2}$ ) | $n$  | $r_0$<br>(arcsec) | $B_r(\text{syst.})$<br>(mag.) | $B_r(\text{integ.})$<br>(mag.) | $\Delta B$<br>(mag.) |
|-------------------|-------------------------|------------------------------|------------------------|------------|--------------------------------------|------|-------------------|-------------------------------|--------------------------------|----------------------|
| <i>1990 data:</i> |                         |                              |                        |            |                                      |      |                   |                               |                                |                      |
| IC 3468           | E/M                     | 14.10                        | 57.63                  | 0.24       | 19.60                                | 0.53 | 0.1817E+01        | 13.97                         | <b>13.97</b>                   | 0.13                 |
| IC 3540           | S0/M                    | 14.77                        | 31.18                  | 0.12       | 19.39                                | 0.72 | 0.2343E+01        | 14.64                         | <b>14.72</b>                   | 0.05                 |
| IC 3653           | E/M                     | 14.56                        | 27.06                  | 0.06       | 18.42                                | 0.64 | 0.1277E+01        | 14.53                         | <b>14.53</b>                   | 0.03                 |
| IC 3773           | d:S0/M                  | 14.11                        | 63.50                  | 0.58       | 18.47                                | 0.45 | 0.6294E+00        | 14.03                         | <b>14.04</b>                   | 0.08                 |
| NGC 4168          | E/M                     | 12.34                        | 110.08                 | 0.24       | 16.09                                | 0.28 | 0.4401E-01        | 12.05                         | <b>12.05</b>                   | 0.29                 |
| NGC 4200          | S0/M                    | 14.01                        | 47.25                  | 0.41       | 17.74                                | 0.42 | 0.3693E+00        | 13.90                         | <b>13.89</b>                   | 0.11                 |
| NGC 4352          | S0/M                    | 13.56                        | 68.08                  | 0.38       | 17.33                                | 0.40 | 0.3009E+00        | 13.50                         | <b>13.49</b>                   | 0.07                 |
| NGC 4374          | E/M                     | 10.10                        | 329.17                 | 0.07       | 9.81                                 | 0.15 | 0.4891E-05        | 9.69                          | <b>9.71</b>                    | 0.40                 |
| NGC 4387          | E/M                     | 13.16                        | 85.61                  | 0.24       | 16.24                                | 0.38 | 0.1708E+00        | 13.14                         | <b>13.13</b>                   | 0.03                 |
| NGC 4406          | S0/M                    | 9.79                         | 484.53                 | 0.40       | 11.59                                | 0.15 | 0.1423E-04        | 9.15                          | <b>9.15</b>                    | 0.64                 |
| NGC 4415          | d:E/M                   | 13.89                        | 56.30                  | 0.16       | 19.45                                | 0.54 | 0.1967E+01        | 13.76                         | <b>13.76</b>                   | 0.13                 |
| NGC 4417          | S0/M                    | 12.01                        | 125.19                 | 0.30       | 14.06                                | 0.28 | 0.1835E-01        | 11.93                         | <b>11.95</b>                   | 0.06                 |
| NGC 4431          | dS0/M                   | 14.21                        | 43.50                  | 0.33       | 19.84                                | 0.54 | 0.2153E+01        | 13.96                         | <b>13.96</b>                   | 0.25                 |
| NGC 4434          | E-S0/M                  | 13.18                        | 65.63                  | 0.14       | 14.94                                | 0.30 | 0.2629E-01        | 13.06                         | <b>13.08</b>                   | 0.10                 |
| NGC 4436          | dE-dS0/M                | 14.15                        | 62.06                  | 0.41       | 18.65                                | 0.42 | 0.5357E+00        | 14.00                         | <b>14.01</b>                   | 0.14                 |
| NGC 4452          | S0/M                    | 12.86                        | 95.38                  | 0.60       | 17.88                                | 0.48 | 0.1011E+01        | 12.89                         | <b>12.83</b>                   | 0.03                 |
| NGC 4458          | E/M                     | 13.07                        | 80.72                  | 0.01       | 15.32                                | 0.29 | 0.2641E-01        | 12.94                         | <b>12.94</b>                   | 0.12                 |
| NGC 4459          | S0/M                    | 11.21                        | 197.98                 | 0.19       | 15.12                                | 0.30 | 0.6466E-01        | 11.29                         | <b>11.15</b>                   | 0.06                 |
| NGC 4464          | E/M                     | 13.53                        | 47.53                  | 0.07       | 15.05                                | 0.36 | 0.6574E-01        | 13.46                         | <b>13.49</b>                   | 0.04                 |
| NGC 4473          | E/M                     | 11.15                        | 231.09                 | 0.39       | 12.34                                | 0.22 | 0.1525E-02        | 11.06                         | <b>11.07</b>                   | 0.08                 |
| NGC 4474          | S0/M                    | 12.50                        | 99.85                  | 0.20       | 15.83                                | 0.33 | 0.9517E-01        | 12.43                         | <b>12.42</b>                   | 0.08                 |
| NGC 4476          | S0/M                    | 13.16                        | 90.77                  | 0.15       | 15.42                                | 0.30 | 0.3278E-01        | 13.07                         | <b>13.09</b>                   | 0.07                 |
| NGC 4478          | E/M                     | 12.42                        | 63.42                  | 0.08       | 16.78                                | 0.50 | 0.8680E+00        | 12.39                         | <b>12.39</b>                   | 0.04                 |
| NGC 4486          | E/M                     | 9.71                         | 410.42                 | 0.35       | 14.43                                | 0.23 | 0.1314E-01        | 9.43                          | <b>9.43</b>                    | 0.27                 |
| NGC 4550          | E-S0/M                  | 12.60                        | 71.24                  | 0.68       | 17.61                                | 0.57 | 0.1665E+01        | 12.58                         | <b>12.57</b>                   | 0.02                 |
| NGC 4551          | E/M                     | 13.11                        | 62.71                  | 0.21       | 17.56                                | 0.50 | 0.9137E+00        | 13.07                         | <b>13.08</b>                   | 0.03                 |
| NGC 4552          | S0/M                    | 10.80                        | 245.11                 | 0.17       | 9.32                                 | 0.15 | 0.2717E-05        | 10.47                         | <b>10.48</b>                   | 0.32                 |
| NGC 4564          | E/M                     | 12.12                        | 109.83                 | 0.40       | 14.92                                | 0.32 | 0.6149E-01        | 12.07                         | <b>12.07</b>                   | 0.06                 |
| NGC 4578          | S0/M                    | 12.46                        | 108.71                 | 0.25       | 15.39                                | 0.28 | 0.2836E-01        | 12.32                         | <b>12.31</b>                   | 0.15                 |
| NGC 4621          | E/M                     | 10.63                        | 310.37                 | 0.09       | 9.87                                 | 0.15 | 0.3820E-05        | 10.29                         | <b>10.30</b>                   | 0.34                 |
| NGC 4638          | S0/M                    | 12.16                        | 82.43                  | 0.38       | 16.07                                | 0.45 | 0.5002E+00        | 12.13                         | <b>12.14</b>                   | 0.02                 |
| NGC 4660          | E-S0/M                  | 12.14                        | 90.29                  | 0.16       | 12.73                                | 0.26 | 0.5285E-02        | 12.06                         | <b>12.07</b>                   | 0.07                 |
| <i>1994 data:</i> |                         |                              |                        |            |                                      |      |                   |                               |                                |                      |
| NGC 4215          | S0/M                    | 12.92                        | 54.25                  | 0.61       | 17.02                                | 0.48 | 0.6589E+00        | 12.95                         | <b>12.88</b>                   | 0.05                 |
| NGC 4255          | S0/M                    | 13.69                        | 48.36                  | 0.38       | 15.92                                | 0.38 | 0.1180E+00        | 13.63                         | <b>13.64</b>                   | 0.04                 |
| NGC 4261          | E/M                     | 11.35                        | 171.60                 | 0.25       | 12.61                                | 0.19 | 0.3345E-03        | 10.99                         | <b>11.00</b>                   | 0.36                 |
| NGC 4268          | S0/M                    | 13.74                        | 46.08                  | 0.44       | 17.58                                | 0.52 | 0.7694E+00        | 13.70                         | <b>13.70</b>                   | 0.03                 |
| NGC 4269          | S0/M                    | 13.86                        | 50.93                  | 0.21       | 9.74                                 | 0.15 | 0.8938E-06        | 13.31                         | <b>13.38</b>                   | 0.48                 |
| NGC 4270          | S0/M                    | 13.20                        | 60.02                  | 0.45       | 17.69                                | 0.54 | 0.1146E+01        | 13.17                         | <b>13.17</b>                   | 0.03                 |
| NGC 4339          | S0/M                    | 12.56                        | 98.48                  | 0.12       | 15.82                                | 0.30 | 0.5332E-01        | 12.41                         | <b>12.41</b>                   | 0.15                 |
| NGC 4342          | S0/M                    | 13.22                        | 39.99                  | 0.23       | 11.72                                | 0.26 | 0.2078E-02        | 13.08                         | <b>13.17</b>                   | 0.06                 |
| NGC 4360          | E/B                     | 13.69                        | 88.99                  | 0.18       | 15.88                                | 0.30 | 0.3175E-01        | 13.60                         | <b>13.61</b>                   | 0.07                 |
| NGC 4365          | E/M                     | 10.72                        | 210.48                 | 0.32       | 12.82                                | 0.19 | 0.5118E-03        | 10.28                         | <b>10.28</b>                   | 0.43                 |
| NGC 4377          | S0/M                    | 12.79                        | 64.20                  | 0.18       | 15.32                                | 0.35 | 0.9057E-01        | 12.72                         | <b>12.73</b>                   | 0.07                 |
| NGC 4472          | E-S0/M                  | 9.21                         | 622.25                 | 0.15       | 13.38                                | 0.20 | 0.2295E-02        | 8.93                          | <b>8.93</b>                    | 0.28                 |
| NGC 4570          | S0-E/M                  | 11.85                        | 65.71                  | 0.69       | 15.87                                | 0.42 | 0.4143E+00        | 11.77                         | <b>11.77</b>                   | 0.08                 |
| NGC 4600          | S0/M                    | 13.60                        | 64.94                  | 0.16       | 19.56                                | 0.67 | 0.3684E+01        | 13.56                         | <b>13.56</b>                   | 0.04                 |
| NGC 4623          | E/M                     | 13.26                        | 66.19                  | 0.55       | 18.09                                | 0.47 | 0.9093E+00        | 13.18                         | <b>13.18</b>                   | 0.08                 |
| NGC 4636          | E-S0/M                  | 10.31                        | 288.01                 | 0.35       | 14.59                                | 0.21 | 0.4698E-02        | 9.79                          | <b>9.79</b>                    | 0.52                 |

Notes: (1) Membership assignments are based on radial velocities: M (for member) if less than 3500 km s $^{-1}$ ; otherwise B (for background). (2)  $B_r(\text{syst.})$  represents systemic total magnitude derived by integrating the best fitting profile parameters from  $r = 0$  to  $\infty$ . (3)  $B_r(\text{integ.})$  represents the sum of  $B_{r < r_{\max}}$  and the integral of the best fitting profile parameters from  $r = r_{\max}$  to  $\infty$ . (4)  $\Delta B = B_{r < r_{\max}} - B_r(\text{integ.})$ . (5) For the sake of consistency, NGC 4215 was not treated differently from the other galaxies when its profile was fitted, even though it probably possesses a ring as noted by Caon et al. (1994). (6) NGC 4342 is also known as IC 3256.

**Table 4.**  $B_T$  values adopted from Michard (1982) in order to provide a consistency check on the improved values listed in Table 3

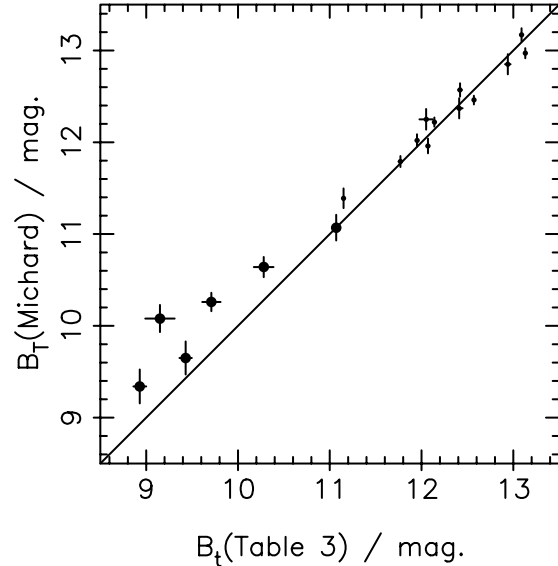
| Designation | VCC type/<br>membership | $B_T$<br>(mag.) | $B_{A_{\max}} - B_T$<br>(mag.) |
|-------------|-------------------------|-----------------|--------------------------------|
| NGC 4124    | S0/M                    | 12.10           | 0.42                           |
| NGC 4168    | E/M                     | 12.25           | 0.45                           |
| NGC 4262    | SB0/M                   | 12.43           | 0.16                           |
| NGC 4267    | SB0/M                   | 11.81           | 0.47                           |
| NGC 4339    | S0/M                    | 12.37           | 0.44                           |
| NGC 4365    | E/M                     | 10.64           | 0.44                           |
| NGC 4374    | E/M                     | 10.26           | 0.40                           |
| NGC 4382    | S0(pec)/M               | 10.03           | 0.33                           |
| NGC 4387    | E/M                     | 12.97           | 0.22                           |
| NGC 4406    | S0/M                    | 10.08           | 0.59                           |
| NGC 4417    | S0/M                    | 12.02           | 0.27                           |
| NGC 4425    | SBa/M                   | 12.75           | 0.18                           |
| NGC 4429    | S0-Sa(pec)/M            | 11.11           | 0.49                           |
| NGC 4435    | SB0/M                   | 11.68           | 0.37                           |
| NGC 4442    | SB0/M                   | 11.32           | 0.28                           |
| NGC 4458    | E/M                     | 12.85           | 0.44                           |
| NGC 4459    | S0/M                    | 11.39           | 0.43                           |
| NGC 4461    | Sa/M                    | 12.08           | 0.31                           |
| NGC 4472    | E-S0/M                  | 9.34            | 0.74                           |
| NGC 4473    | E/M                     | 11.07           | 0.56                           |
| NGC 4474    | S0/M                    | 12.57           | 0.29                           |
| NGC 4476    | S0/M                    | 13.17           | 0.29                           |
| NGC 4477    | SB0-SBa/M               | 11.45           | 0.49                           |
| NGC 4486    | E/M                     | 9.65            | 0.72                           |
| NGC 4503    | Sa/M                    | 12.13           | 0.38                           |
| NGC 4526    | S0/M                    | 10.70           | 0.15                           |
| NGC 4550    | E-S0/M                  | 12.46           | 0.19                           |
| NGC 4564    | E/M                     | 11.96           | 0.32                           |
| NGC 4570    | S0-E/M                  | 11.79           | 0.24                           |
| NGC 4596    | SBa/M                   | 11.50           | 0.44                           |
| NGC 4638    | S0/M                    | 12.22           | 0.20                           |
| NGC 4649    | S0/M                    | 9.88            | 0.80                           |

Notes: (1) The  $B_{A_{\max}} - B_T$  extrapolation values listed here are based on the maximum aperture for which a reliable measurement was obtained. (2) Membership assignments are based on radial velocities: M (for member) if less than  $3500 \text{ km s}^{-1}$ . (3) NGC 4124 is not listed in the VCC. Its type was taken from the RC3 instead.

However, our value of  $B_t = 13.82$  is in excellent agreement with Michard's (1982) value of  $B_T = 13.79$ .

In the cases of the six bright objects shown in Figure 2 for which  $n < 0.25$  then (see also Table 5), the large systematic differences between our new  $B_t$  values and Michard's (1982)  $B_T$  ones cannot be the result of zero-point differences, but must primarily be due to the different extrapolations applied. The RC2 set of standard growth curves available to Michard (1982) did not include any curve specific to galaxies more centrally concentrated than  $n = 0.25$  objects, and so Michard (1982) necessarily applied the growth curve specific to the  $n = 0.25$  case to his most centrally concentrated objects.

Consistency checks on our extrapolation terms for all of the objects listed in Table 3, including the most centrally concentrated ones, can be provided by comparisons with Caon et al.'s (1990; 1994) total magnitudes. It was found that for objects of  $n \geq 0.25$  (with a scatter of



**Figure 2** A comparison between the new  $B_t$  values derived from Caon et al.'s (1990; 1994) surface brightness profiles (Table 3) and Michard's (1982)  $B_T$  values (Table 4) for the 18 galaxies in common between Tables 3 and 4. The datapoints represent individual galaxies and the equality line is shown for reference. The error bars only represent uncertainties in the extrapolation terms, and have been set to one quarter of the extrapolation terms in magnitude. Larger '•' symbols have been used to distinguish the six objects for which  $n < 0.25$ . These objects are listed in Table 5. If these objects are excluded, the mean  $B_T$  (Table 4) –  $B_t$  (Table 3) offset for the remaining 12 objects is only  $+0.03(\pm 0.04)$  magnitude.

0.24 magnitude about the mean offset)

$$\begin{aligned} & \text{Extrapolated } B_T \text{ (Caon et al.)} - B_t \text{ (Table 3)} \\ & = -0.06(\pm 0.05) \text{ mag.} \end{aligned} \quad (1)$$

and (with a scatter of 0.14 magnitude)

$$\begin{aligned} & \text{Integrated } B_T \text{ (Caon et al.)} - B_t \text{ (Table 3)} \\ & = -0.06(\pm 0.02) \text{ mag.} \end{aligned} \quad (2)$$

where 'extrapolated' values are from Caon et al. (1990) Table I and 'integrated' values are from Caon et al. (1990) Table VI and Caon et al. (1994). For objects of  $n < 0.25$  on the other hand, it was found that (with a scatter of 0.31 magnitude)

$$\begin{aligned} & \text{Extrapolated } B_T \text{ (Caon et al.)} - B_t \text{ (Table 3)} \\ & = +0.40(\pm 0.12) \text{ mag.} \end{aligned} \quad (3)$$

and (with a scatter of 0.17 magnitude)

$$\begin{aligned} & \text{Integrated } B_T \text{ (Caon et al.)} - B_t \text{ (Table 3)} \\ & = +0.05(\pm 0.05) \text{ mag.} \end{aligned} \quad (4)$$

In the latter case, if NGC 4406 were excluded,<sup>3</sup> we find that (with a scatter of 0.09 magnitude)

$$\begin{aligned} & \text{Integrated } B_T \text{ (Caon et al.)} - B_t \text{ (Table 3)} \\ & = +0.01(\pm 0.03) \text{ mag.} \end{aligned} \quad (5)$$

<sup>3</sup>As noted by Caon et al. (1990), NGC 4406 overlaps with NGC 4374 at the  $\mu_B = 26 \text{ mag. arcsec}^{-2}$  isophote and this may be the main cause of the 0.48 magnitude discrepancy found for this galaxy.

**Table 5. A comparison between the total magnitude values derived by Michard (1982), Caon et al. (1990; 1994) and the author for galaxies listed in Table 3 that were found to possess luminosity profiles of  $n < 0.25$** 

| Designation | $n$<br>Table 3 | $B_T$ (mag.)      | $B_T$ (mag.)                  | $B_T$ (mag.)                   | $B_T$ (mag.)          | $B_i$ (mag.) |
|-------------|----------------|-------------------|-------------------------------|--------------------------------|-----------------------|--------------|
|             |                | Michard<br>(1982) | Caon et al.<br>(1990) Table I | Caon et al.<br>(1990) Table VI | Caon et al.<br>(1994) | Table 3      |
| NGC 4261    | 0.19           | –                 | –                             | –                              | 11.03                 | 11.00        |
| NGC 4269    | 0.15           | –                 | –                             | –                              | 13.32                 | 13.38        |
| • NGC 4365  | 0.19           | 10.64             | –                             | –                              | 10.35                 | 10.28        |
| • NGC 4374  | 0.15           | 10.26             | 10.26                         | 9.71                           | –                     | 9.71         |
| • NGC 4406  | 0.15           | 10.08             | 10.06                         | 9.63                           | –                     | 9.15         |
| • NGC 4472  | 0.20           | 9.34              | –                             | –                              | 8.87                  | 8.93         |
| • NGC 4473  | 0.22           | 11.07             | 11.10                         | 11.02                          | –                     | 11.07        |
| • NGC 4486  | 0.23           | 9.65              | 9.58                          | 9.48                           | –                     | 9.43         |
| NGC 4552    | 0.15           | (10.91)           | 10.78                         | 10.38                          | –                     | 10.48        |
| NGC 4621    | 0.15           | (10.83)           | 10.76                         | 10.30                          | –                     | 10.30        |
| NGC 4636    | 0.21           | –                 | –                             | –                              | 10.01                 | 9.79         |

Notes: (1) Three objects were not observed by Michard (1982): NGC 4261, 4269, and 4636, whilst Michard's (1982)  $B_T$  values for a further two are listed in parentheses because they were flagged by him as unreliable. Only the six objects for which Michard (1982) obtained reliable  $B_T$  measurements appear on Figure 2. These objects are flagged with '•' symbols.

The agreement with Caon et al.'s (1990; 1994) integrated magnitudes is therefore very good and much better than with Caon et al.'s (1990) extrapolated values. This is reassuring because integrations to large radii should yield relatively unbiased (even if often relatively noisy) estimates of total magnitude.<sup>4</sup> The disagreements with Caon et al.'s (1990) extrapolated magnitudes and Michard's (1982) values at the bright end are therefore no cause for concern. Both of the latter sources of magnitude estimates are strongly affected by the  $r^{1/4}$  law extrapolations applied — especially in the cases of the most centrally concentrated objects.

As far as our profile fits and parameterisations for the most centrally concentrated objects are concerned, the almost perfect agreement between the  $B_i$  (systemic) and  $B_T$  (integrated to  $r_{\max}$  and extrapolated) values listed in Table 3<sup>5</sup> would appear to confirm the superiority of our fits with respect to ones rigidly assuming  $n = 0.25$ . Furthermore, our finding that the profiles of the brightest early-type Virgo galaxies are best fitted by Sérsic (1968) profiles of  $n < 0.25$  is in full agreement with Graham et al.'s (1996) conclusion that brightest cluster galaxies typically have  $n < 0.25$ .<sup>6</sup>

## 6 The Scope of this Dataset

Although no new observations have been presented in this paper, 13 new  $B_i$  values have been derived for VPC objects of intermediate apparent brightnesses but previously lacking  $B_i$  estimates. Also, 48 new  $B_i$  values

have been derived for bright Virgo galaxies through the re-analysis of existing photometry. Combining these 61 new  $B_i$  values (as tabulated in Tables 2 and 3) with the VPC enables us to define a reliable dataset covering a subset of Virgo galaxies spanning a range in apparent luminosity of 10 000 (or 10 magnitudes). Interestingly we find that the brightest Virgo galaxy is NGC 4472 (=M49) (8.93 magnitude) followed by NGC 4406 (=M86) (9.15 magnitude). This leaves NGC 4486 (=M87) (9.43 magnitude) in third place. Of course, should there be significant spatial depth in the distribution of these objects, their relative rankings in terms of absolute magnitude may be quite different. Recent distance estimates are available for two of these giants from Gavazzi et al. (1999), who find NGC 4472 to be 0.24 magnitude closer to us in distance-modulus space than NGC 4486. This would suggest that in terms of intrinsic luminosity NGC 4472 is only 0.26 magnitude brighter than NGC 4486, even though in terms of apparent brightness it is 0.50 magnitude brighter.

The main limitations of this dataset are: (1) it is restricted to elliptical and lenticular types at the bright end; (2) its coverage of 14th magnitude objects is relatively thin (only eight objects in total); and (3) large extrapolations<sup>7</sup> were necessary for some objects. As far as the extrapolations are concerned though, we have good reason to believe from Young et al. (1998) that for most bright early-type and fainter galaxies of all types  $t$ -system total magnitudes are relatively insensitive to the exact surface brightness of the limiting isophote.

At this stage, it is also worth mentioning that it will become evident from future papers in this series why most other sources were not included in our dataset. We have therefore chosen only to discuss the positive attributes of the selected sources here rather than the limitations of

<sup>4</sup>In the case of Caon et al.'s (1990; 1994) integrated magnitudes, there must still be a weak dependence on the  $r^{1/4}$  law assumption because the determination of the radial limit of each integration was based on an  $r^{1/4}$  law extrapolation.

<sup>5</sup>Of the eleven galaxies listed in Table 5, this concordance is at the 0.07 magnitude level in one case and at the 0.02 magnitude level in another, but it is at the 0.01 magnitude level or better in all nine other cases.

<sup>6</sup> $n > 4$  in their notation.

<sup>7</sup>Extrapolations of greater than 0.5 magnitude were necessary not only for some faint dwarf ellipticals but also for two Table 2 and a further two Table 3 objects.



the others. As will be demonstrated, any minor error in the present dataset pales into virtual insignificance when most other sources of magnitudes for Virgo galaxies are investigated.

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### References

- Binggeli, B., Sandage, A., & Tammann, G. A. 1985, *AJ*, 90, 1681 (VCC)
- Caldwell, N. 1983, *AJ*, 88, 804
- Caon, N., Capaccioli, M., & D'Onofrio, M. 1994, *A&A*, 106, 199
- Caon, N., Capaccioli, M., & Rampazzo, R. 1990, *A&A*, 86, 429
- Davies, J. I., Phillipps, S., Cawson, M. G. M., Disney, M. J., & Kibblewhite, E. J. 1988, *MNRAS*, 232, 239
- de Vaucouleurs, G., de Vaucouleurs, A., & Corwin, H. G. 1976, *Second Reference Catalogue of Bright Galaxies* (Austin: University of Texas) (RC2)
- de Vaucouleurs, G., de Vaucouleurs, A., Corwin, H. G., Buta, R. J., Paturel, G., & Fouque, P. 1991, *Third Reference Catalogue of Bright Galaxies* (New York: Springer-Verlag) (RC3)
- Gallagher, J. S., & Hunter, D. A. 1986, *AJ*, 92, 557
- Gavazzi, G., Boselli, A., Scoddeggio, M., Pierini, D., & Belsole, E. 1999, *MNRAS*, 304, 595
- Graham, A., Lauer, T. R., Colless, M., & Postman, M. 1996, *ApJ*, 465, 534
- Hill, G. 1982, *Publ. Dominion Astrophysical Observatory*, 16, 67
- Michard, R. 1982, *A&A*, 49, 591
- Schröder, A., & Visvanathan, N. 1996, *A&A*, 118, 441
- Sérsic, J. L. 1968, *Atlas de Galaxias Australes* (Cordoba, Argentina: Observatorio Astronómico de Córdoba)
- Tift, W. G. 1973, *PASP*, 85, 283
- Young, C. K. 1994, D.Phil. Thesis, University of Oxford
- Young, C. K. 1997, in *Galaxies, Proceedings of 21st Century Chinese Astronomy Conference*, ed. K. L. Chan & K. S. Cheng (Singapore: World Scientific)
- Young, C. K., & Currie, M. J. 1998a, *A&A*, 127, 367 (VPC)
- Young, C. K., & Currie, M. J. 1998b, *A&A*, 333, 795
- Young, C. K., Metcalfe, N., Zhu, J., Wu, H., & Chen, J. S. 1998, *A&A*, 130, 173
- Zwicky, F., & Herzog, E. 1963, *Catalogue of Galaxies and of Clusters of Galaxies*, 2 (Pasadena: California Institute of Technology)
- Zwicky, F., Herzog, E., & Wild, P. 1961, *Catalogue of Galaxies and of Clusters of Galaxies*, 1 (Pasadena: California Institute of Technology)