FIVE CRUCIAL TESTS OF THE EXTRAGALACTIC DISTANCE SCALE USING THE GALAXY AS FUNDAMENTAL CALIBRATOR

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The traditional approach to the extragalactic distance scale has been through several levels of primary, secondary and tertiary indicators of increasing range and decreasing precision. This piecemeal approach, fraught with the danger of cumulative errors, has led in recent years to two widely divergent scales, the "long" scale of Sandage and Tammann (1974-1982), leading to $H_o' \simeq 50$ km s^{-1} Mpc^{-1}, and the "short" scale of the author (1978-79), leading to $H_o \simeq 100$ (de Vaucouleurs and Bollinger 1979; de Vaucouleurs and Peters 1981; de Vaucouleurs et al. 1981). The divergence, increasing from $\sim$ 0.4 mag in the Local Group to $\sim$ 1.2 mag at the distance of the Virgo Cluster, indicates that at least one of the scales is not linear (de Vaucouleurs 1981).

Five crucial tests of the two scales have been performed by means of direct comparisons of corresponding metric, photometric and kinematic parameters of our Galaxy and other galaxies. These parameters (Table 1) are now known well enough to be used as fundamental calibrators for a variety of distance indicators without recourse to galaxies in the Local Group and nearby groups. The basic scale length of the Galaxy, the galactocentric distance of the Sun, $R_\odot$, in particular, is now determined within $\pm$15% by two independent primary distance indicators, the mean magnitudes of RR Lyr and long-period (Mira-type) variables which are both fixed with mean errors of 0.1-0.2 mag by fundamental methods (de Vaucouleurs 1978a, Glass and Feast 1982).

The five tests involve (i) the B- and H-band versions of the Tully-Fisher (1977) relation between absolute magnitude and maximum rotation velocity (or 21cm line width), (ii) the B- and V-band versions of the Faber-Jackson (1976) relation between the absolute magnitude of the spheroidal component and its central velocity dispersion, (iii) the relation between total B-band absolute magnitude (or linear isophotal diameter) and luminosity index (de Vaucouleurs 1979a, b), (iv) several metric and photometric parameters of four galaxies which, from a multiplicity of indices, must, on the average, precisely match our Galaxy in all respects, (v) the mean absolute magnitudes of globular clusters in the Virgo E cluster and in the Galaxy and their implications for $R_\odot$ and

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Table 1

Basic Scale Factors of the Galaxy

Description	Symbol	Value	m.e.
Galactic constants			
Morphological type, SAB(rs)bc	T	4	0.5
Galactocentric distance of Sun (kpc)	$R_\odot$	8.5	0.5
Total B-band absolute magnitude (face-on)	$M_T^o(B)$	-20.2	0.15
Total colour indices (face-on)	$(B-V)_T^o$	0.53	0.04
- - -	$(U-B)_T^o$	-0.06	0.05
Total B-band magnitude of spheroidal component	$M_I^o(B)$	-18.2	0.3
Colour index of spheroidal component	$(B-V)_I^o$	0.65	0.05
H-band absolute magnitude (X = logA/D_o = -0.5)	$M^c(H)$	-22.55	0.23
Rotation velocity of LSR (km s^{-1})	$V(R_\odot)$	220	15
Central velocity dispersion of spheroidal component	$\sigma_v(0)$	130	7
Isophotal diameter at μ_B = 25.0 mag $arcsec^{-2}$	$D_o/2R_\odot$	1.44	-
Effective diameter (B-band)	$D_e/2R_\odot$	0.63	-
Diameter of (rs) structure ("3 kpc arm")	$D_r/2R_\odot$	0.34	-
Related constants			
Mean V-band absolute magnitude of ab-type metal-poor RR Lyr variables of P > 0.42 d	$<M_v(RR)>$	+0.8	0.15
Zero point of bolometric period-luminosity relation of long period (Mira-type) variables	$<M_{bol}(O)>$	+0.76	0.1:
Mean V-band absolute magnitude of galactic globular clusters	$<M_v(\oplus)>$	-7.2	0.2:

for the mean absolute magnitudes of the RR Lyr and Mira variables.

All tests confirm within 0.1-0.2 mag both the linearity and the zero point of the "short" distance scale previously derived from primary, secondary and tertiary indicators, and the validity of the distance scale based on globular clusters (Hanes 1977, 1979; de Vaucouleurs 1977). All tests reject the "long" scale at extremely high levels of significance. In particular, several of the most direct and critical tests demonstrate that the long scale could be reconciled with the galactic parameters only if $R_\odot$ were changed from 8.5 to $\sim$ 15 kpc, the mean absolute magnitude $<M_v>$ of the RR Lyr variables from +0.8 to -0.46 and the zero point of the bolometric period-luminosity relation for Mira variables from +0.76 to -0.5.

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Table 2

Probabilities $P(\mu'_o)$ that the Metric, Photometric and Kinematic Parameters of the Galaxy are Consistent with the Long Distance Scale

Tests	Parameters		$P(\mu'_o)$
Tully-Fisher relations in Virgo S cluster	$R_\odot$, V_o, M_T^o	B-band	$1.5.10^{-9}$
		H-band	$2.\ 10^{-6}$
Faber-Jackson relations in Virgo E cluster	$R_\odot$, $\sigma_v(0)$, M_T^o, T, Δm(E,S)		$<10^{-5}$
Magnitude-diameter-luminosity index relations for 458 spirals	R_o, M_T^o, D_o, Λ_c		$<10^{-7}$
Magnitude and diameters of Galaxy compared to its "sosies"	$R_\odot$, M_T^o, D_o, D_e, D(r)		$<10^{-8}$
Mean magnitudes of globular clusters in Virgo E cluster	$R_\odot$, M_T^o, $m_v(\Theta)$, M_v(RR), $M_{bol}(0)$ (Miras)		$<10^{-5}$

The most probable value of the Hubble constant derived from the various indicators when their zero points are fixed by the basic scale factors of our Galaxy is $H_o = 95 \pm 10$ km s^{-1} Mpc^{-1}, in close agreement with our previous determinations.

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