INVITED REVIEW

Cepheid Variables as Extra-Galactic Distance Indicators

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Summary

The role of cepheid variables in establishing the inner distance scale to nearby galaxies is discussed. Emphasis is placed on the necessity for broad wavelength coverage in attempting to account for metallicity differences and reddening internal to the parent galaxies. In addition linear detectors are essential in minimizing the effects of any unresolved background contibution to the photometry. Recent infrared observations of Cepheids in Local Group galaxies are surveyed and all published data on extra-galactic Cepheids are presented for convenient access.

I. Introduction

Cepheid variables are no strangers to the extragalactic distance scale. On the contrary it can be argued that they are the fundamental basis for it. From Leavitt and Shapley, to Hubble, Baade and Sandage, and now to the host of other workers in the field, Cepheids have acted as the cornerstone in establishing the distances to nearby galaxies.

It is not without some trepidation that such reliance has been placed on a single primary distance indicator, but the alternatives are limited and at best statistical in nature. Cepheids are relatively bright, they are plentiful, their properties are stable with time. We have every reason to believe that we understand the basic physics governing the pulsation and we now have the strongest indicators ever that we have a reliable calibration and systematically correct data available to us. With such a firm basis for proceeding it is not unlikely that we have missed something vital. What that is, we of course don't know, but workers on the extragalactic distance scale are notoriously optimistic. This review will carry on with that tradition.

II. Observing in the Blue

So often the available technology has defined the ways in which we can practice our science of observing. Initially the photographic plate provided a unprecedented opportunity for astronomers. It immediately produced semi-quantitative, permanent and panoramic surveys of the sky. But its non-linear response demanded the utmost in care in calibration and unending external checks and verification. As a wide-

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field detector, the photographic plate in combination with the appropriate telescope, was and still is superb; as a means of quantifying data to the systematic precision needed for the distance scale, numerous difficulties persisted.

Perhaps just as unfortunate as the non-linear intensity response of the photographic plate, is the fact that the spectral response of most emulsions was dictated again by technology rather than astronomical imperatives. Astronomers had no option but to observe at wavelengths accessible to the available detectors. Certainly the choice provided originally (i.e., that of a photographic blue magnitude or a photovisual green magnitude) seemed innocuous enough. And for many purposes this "forced choise" was fortuitously good; the blue/green combination of magnitudes acted as excellent luminosity and temperature discriminants for the majority of visible stars. This was evidenced by the successful construction of colour-magnitude diagrams for dozens of star clusters, and by the discovery of hundreds of galactic and extragalactic Cepheid variables which undergo temperature-induced light variations of a magnitude or more at the blue wavelengths. Had the first panoramic detectors been sensitive to the infrared, the discovery process would have been spectacular; but as we shall see it might not have been quite so uncertain.

With the advent of photoelectric devices the situation changed fundamentally on one front, but stood rigidly still on the other. The linear intensity response of the photoelectric photometers, available after World War II, eliminated the fear of continued scale errors in stellar magnitudes; but all of the existing photographic studies needed to be redone if old errors were to be eliminated. Because the photoelectric photometers were single channel devices, sample size had to be sacrificed for systematic accuracy. It should nevertheless be emphasized that despite their limited photometric capabilities, photographic surveys were, and continued for many decades to be the principal means by which new Cepheids could be discovered and their periods determined. The panoramic surveys were an absolutely necessary first step in the course of accurately calibrating and applying the Period-Luminosity relation beyond the Galaxy.

III. Testing the Calibration

A fine review of the contemporary studies of the Cepheids in the Magellanic Clouds is given by Feast (1984) in these Proceedings so the specifics of that review need not be repeated here. However, because of their proximity and their abundant supply of Cepheids, the Magellanic Clouds, cannot be over-looked because, as always, they provide the testing ground for all fundamental work on the distances to nearby galaxies. In the context of this review, the importance of the Magellanic Clouds cannot be over-emphasized. If we cannot successfully intercompare the Cepheids in the two Magellanic Clouds, we certainly cannot go further afield with any confidence. For instance, knowing that the Large and Small Magellanic Clouds differ in mean metallicity by a factor of three or so, is this idfference in composition reflected in any of the observed properties of the Cepheids which must be taken

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into account when using these stars as distance indicators? Specifically, is the slope, the zero point or the width of the Period-Luminosity relation systematically shifted in the SMC with respect to the LMC? If the answer is yes, can we then understand the shift, can we correct for it, or can we avoid it by undertaking new and specific observations?

In some of the first modern photographic studies of the Cepheids in the Magellanic Clouds, claims were made that comparisons of the Period-Colour distributions with that of the Cepheids in the Galaxy, indicated that differences existed between the two populations. The SMC Cepheids were claimed to be redder than their galactic counterparts and this difference was presumably because of the different metallicities of the two systems. Unfortunately, photographic colours are notoriously susceptible to slight scale errors and therefore required confirmation.

It was not until the photoelectric study of the modest sample of Cepheids in each of the Magellanic Clouds, undertaken by Gascoigne and Kron (1965) and Gascoigne (1969), that the question of colour differences could be reliably discussed. The photoelectric studies indicated for the shortest-period Cepheids in the Small Magellanic Cloud that they might be systematically bluer than Cepheids of similar period, observed in the Large Cloud and the Galaxy. The colour difference was now in the opposite sense from the photographic survey, but nonetheless it was concluded that differences in metallicity between the two galaxies were the cause of the colour difference.

It was later argued that the colour difference of the ensemble might be only a reflection of the different degree of filling of the universal instability strip. Given a large instability strip which is defined to be independent of metallicity variations itself, there is room to postulate that low metallicity systems preferentially populate the blue side of the short-period portion of the strip, while high-metallicity systems, such as our galaxy, preferentially have Cepheids which reside toward the red edge of the instability strip. This population effect will manifest itself in different Period-Colour distributions and in different mean Period-Luminosity relations; but if the strip itself is invariant to metallicity then a Period-Luminosity-Colour relationship should be sufficient to define a unique luminosity for each star, compensating for this class of postulated, but optimistically harmless, effect of metallicity.

Some support for this suggestion was obtained from stellar evolution theory which indicated that stars in the cepheid-phase of evolution (core He burning) make deeper excursions to the blue when their interior metallicity is low. Thus stars of low metallicity might be expected to preferentially populate blue parts of the instability strip. But the logic is not complete. If one allows metallicity to effect the theoretical interior solution, one must also consider the effects on the atmosphere, (i.e., the observed colours at fixed effective temperature and bolometric luminosity) and ultimately one must consider the effects on the pulsational characteristic of the Cepheids (i.e., the effects on the position of the instability strip itself).

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The first effect was estimated by Gascoigne (1974) who used the synthetic spectra of Bell and Parsons (1972) to estimate the differential colour effect of metallicity variations on the atmospheres of Magellanic Cloud Cepheids. He concluded that a correction of -0.4 to the V magnitude was probably in order for a star with a metallicity typical of an SMC Cepheid as compared to one with a solar abundance. The latter effect, that of the calculating the position of the instability strip as a function of metallicity was undertaken by Iben and Tuggle (1970). They parameterized the position of the blue edge of the instability strip in terms of the input metallicity as well as the helium abundance; and gave explicit formulae for the Period-Luminosity-Colour relation also as a function of those parameters of the models.

But as secure as the theory might appear, the necessary corrections were becoming rather appreciable. Even for workers in the extragalactic distance scale these uncertainties in the cepheid calibration started to sound unacceptably large, and some looked afield for other distance indicators or at very least cast a suspicious glance at distances which relied heavily on cepheid variables. But the worst fears however were not to be realized, and so now with a better understanding of the problems and no obvious contenders for the better distance indicator, Cepheids are seeing a renewed interest in their precise calibration.

In summary, there is good reason to expect that in the blue and visual regions of the spectrum, atmospheric metallicity effects can have significant observational effects on the magnitudes and colours of Cepheids, through line blanketing in the ultraviolet and blue, and energy redistribution towards the visual and red. In addition, the evolutionary tracks will indipendently respond to differences in the interior metallicities of the stars, and finally, the instability strip itself is probably a function of metallicity as well. Attempts to map some of these three effects onto the observational data have been made, most recently by the South African workers, but much work remains to be done.

Still, perhaps the biggest single concern in attempting to make serious corrections for metallicity variations, especially for the blue wavelengths, is the additional corrections for individual reddening which must be applied before any other analysis. Extinction and reddening is suffered by the Cepheid's light due to dust internal to the parent galaxy and due to a foreground galactic component. Without prior knowledge of the intrinsic colours of the individual Cepheids concerned, the reddening and metallicity effects are difficult to disentangle. Explicit (Martin, Warren, and Feast 1979) and implicit (Madore 1982) attempts have been made but the results are equivocal. If it is our intention to study the intrinsic properties of Cepheids at all wavelengths then many effects await our considered attention; if we need to use Cepheids as a tool and a probe then perhaps we can judiciously choose the best properties now that a broad spectrum of observations are relatively accessible.

IV. Moving to the Red

Rather than confront the problems of reddening and atmospheric metallicity variations head on, it is now possible to avoid those problems by obtaining new observations at wavelengths considerably less sensitive to obscuration and line blanketing. This side-stepping of the problem has come about with the availability of new, and sensitive detectors which allow the observations to be made in the near-infrared. Detailed justifications for the expected advantages were given by McGonegal et al. (1982), and the empirical justification is still gaining momentum with each new galaxy that is observed. It appears that from a purely empirical and pragmatic point of view, observations of Cepheids made in the red and near infrared are insensitive to most of the above problems which plague the optical observations of the past. Furthermore, the reduced response of the infrared portion of the stellar spectrum to temperature variations means that both the width of the observed instability strip and the periodic light variations of individual Cepheids are so reduced in the infrared that single observations, made at randomly chosen times, give unexpectedly accurate distances.

V. A Survey of Modern Studies of Extra-Galactic Cepheids

a) The Magellanic Clouds

The published UBVRI modern photometric data are compiled for the LMC and SMC, respectively in Tables 1 and 3. The final columns in those tables also present the near-infrared data avilable to date; the first row contains the random-phase observation which results in the predicted time-averaged magnitude (based on the methods outlined in Welch et al. 1984) given in the second row. A compilation of references to modern observations in all photometric systems is given in Tables 2 and 4.

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TABLE 1

Large Magellanic Cloud Cepheid Photometry

No.	P(days)	log P	V	U-B	B-V	V-R	V-I	J	H	K
S 65-48	250.	2.398	09.64		0.66	0.31	0.60	08.71	08.48	08.37
S 65-08	250.	2.398	10.00		0.98	0.43	0.81	08.72	08.46	08.35
HV 883	134.0	2.127	12.12	0.83	1.18	0.59	1.09	10.29	09.88	09.73
								10.23	09.88	09.73
HV 2447	119.3	2.077	11.99	1.12	1.26	0.60	1.12	09.97	09.57	09.42
								10.07	09.58	09.44
HV 2883	108.0	2.033	12.41	1.25	1.23	0.57	1.07	10.90	10.52	10.40
								10.54	09.97	09.81
HV 5497	98.86	1.995	11.92	1.07	1.20	0.58	1.11	09.99	09.64	09.52
								10.11	09.62	09.54
HV 2827	78.89	1.897	12.30		1.24		1.08	10.25	09.87	09.79
								10.37	09.93	09.83
HV 2369	48.31	1.684	12.62	0.84	0.96	0.49	0.97	10.70	10.35	10.26
								10.90	10.48	10.41
HV 953	47.89	1.680	12.28	0.68	0.87	0.45	0.89	10.65	10.28	10.18
								10.73	10.38	10.37
HV 900	47.53	1.677	12.77	0.79	0.92		0.92	11.21	10.91	10.82
								10.95	10.68	10.66
HV 877	45.16	1.655	13.41	0.98	1.20		1.19			
								11.25	10.83	10.73
HV 2338	42.15	1.625	12.79	0.85	0.94		0.95	11.12	10.88	10.80
								11.26	10.84	10.77
HV 2257	39.29	1.592	13.03	0.82	0.96		1.04	11.60	11.16	11.04
								11.76	11.30	11.17
HV 909	37.57	1.575	12.76	0.86	0.80		1.01	11.44	11.03	10.93
								11.50	11.10	11.01
HV 879	36.81	1.566	13.35		1.03		1.06			
								11.90	11.47	11.32
HV 2294	36.52	1.563	12.64	0.68	0.83	0.44	0.87	11.23	10.82	10.74
								11.25	11.35	10.77

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TABLE 1 (cont.)

Large Magellanic Cloud Cepheid Photometry

No.		P(days)	log P	V	U-B	B-V	V-R	V-I	J	H	K
HV	881	35.76	1.553	13.14	0.80	0.88					
									11.48	11.00	10.88
HV	873	34.35	1.536	13.52	0.81	1.09			11.77	11.40	11.29
									11.65	11.18	11.07
HV	882	31.81	1.503	13.42	0.74	0.93					
HV	899	31.03	1.492	13.43	0.81	0.94		1.10			
HV	1002	30.47	1.484	12.95	0.68	0.77	0.41	0.79	11.39	11.20	11.14
									11.48	11.11	11.04
HV	875	30.36	1.482	13.04	0.54	0.80					
HV	8036	28.38	1.453	13.60		0.90					
HV	2251	27.99	1.447	13.10		0.75			11.78	11.37	11.29
									11.66	11.23	11.12
HV	1023	26.61	1.425	13.74		1.04		1.06			
HV	902	26.36	1.421	13.22		0.70			12.09	11.74	11.66
									11.77	11.47	11.17
HV	12815	26.18	1.418	13.46		0.95		1.03			
HV	889	25.85	1.412	13.71	0.73	1.00					
HV	1003	24.43	1.388	13.25		0.71			11.66	11.32	11.27
									11.82	11.45	11.36
HV	1013	24.10	1.382	13.83		1.04		0.96			
HV	886	23.97	1.380	13.34	0.73	0.88			12.09	11.79	11.72
									11.94	11.63	11.57
HV	878	23.30	1.367	13.57	0.67	0.90			12.13	11.72	11.61
									12.07	11.73	11.68

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TABLE 1 (cont.)

Large Magellanic Cloud Cepheid Photometry

No.	P(days)	log P	V	U-B	B-V	V-R	V-I	J	H	K
HV 2749	23.12	1.364	14.73		1.24			12.43	11.92	11.78
								12.42	11.89	11.76
U 1	22.54	1.353	14.10		0.98					
U 11	20.07	1.303	13.99	0.88	0.86					
HV 2793	19.19	1.283	14.09		1.01		1.08	12.55	12.16	12.04
								12.45	12.12	12.02
HV 1005	18.71	1.272	13.96		0.82					
HV 2836	17.62	1.246	14.62		1.01		1.13			
HV 2580	16.94	1.229	13.96		0.75		0.86			
								12.49	12.08	12.06
HV 2549	16.18	1.209	13.70		0.72					
HV 2262	15.85	1.200					0.92			
HV 12471	15.85	1.200	14.68		0.99					
HV 2324	14.45	1.160	14.35		0.85		0.92			
HV 5655	14.22	1.153					0.95			
HV 955	13.74	1.138	14.07		0.73			12.87	12.52	12.41
								12.70	12.30	12.20
HV 2352	13.61	1.134	14.17		0.75		0.86			
HV 2579	13.43	1.128	13.95		0.66					
HV 997	13.15	1.119	14.52		0.85		0.95			

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TABLE 1 (cont.)

Large Magellanic Cloud Cepheid Photometry

No.	P(days)	log P	V	U-B	B-V	V-R	V-I	J	H	K
HV 2260	13.00	1.114	14.86		0.89		1.00			
HV 2527	12.94	1.112	14.59		0.80			12.92	12.65	12.55
								11.76	11.30	12.61
HV 12253	12.56	1.099	14.41		0.76					
HV 12716	11.24	1.051	14.70		0.76					
HV 2864	10.99	1.041	14.70		0.79		0.89			
HV 12248	10.91	1.038	14.47		0.75					
HV 2432	10.91	1.038	14.23		0.52			13.10	12.79	12.70
								12.94	12.60	12.57
HV 6105	10.45	1.019	14.91		0.79					
HV 12474	9.84	0.993	14.65		0.69					
HV 2301	9.51	0.978	13.94		0.84					
HV 971	9.29	0.968	14.43		0.68					
HV 12816	9.21	0.960	14.51		0.57		0.72			
HV 12717	8.85	0.947	14.69		0.70					
HV 12452	8.73	0.941	14.79		0.71					
HV 2733	8.73	0.941	14.69		0.62		0.76			
HV 2854	8.63	0.936	14.64		0.72		0.78			

TABLE 1 (cont.)

Large Magellanic Cloud Cepheid Photometry

No.	P(days)	log P	V	U-B	B-V	V-R	V-I	J	H	K
HV 12823	8.30	0.919	14.57		0.55					
HV 12700	8.15	0.911	14.85		0.73		0.75	13.44	13.09	13.04
								13.44	13.14	13.08
HV 12976	7.85	0.895	14.99		0.74					
HV 12079	6.93	0.841	14.94		0.66					
HV 2694	6.93	0.841						13.54	13.26	13.19
								13.58	13.31	13.24
HV 2405	6.92	0.840						13.91	13.56	13.46
								13.82	13.47	13.54
HV 2279	6.90	0.839						13.12	12.75	12.65
HV 914	6.89	0.838						13.49	13.22	13.15
								13.49	13.24	13.23
HV 2337	6.87	0.837						13.80	13.54	13.41
								13.62	13.35	13.23
HV 13048	6.86	0.836						13.58	13.29	13.23
								13.66	13.40	13.32
HV 6065	6.84	0.835						13.79	13.46	13.38
								13.87	13.51	13.44
HV 12797	6.82	0.834						13.42	13.16	13.11
								13.52	13.17	13.13
HV 2523	6.78	0.831						13.16	12.71	12.63
HV 12077	5.05	0.703	15.30		0.61					
HV 6093	4.79	0.680	15.35		0.64			14.26	13.96	13.81
								14.16	13.86	13.72
HV 12231	4.75	0.677	15.43		0.64					

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TABLE 1 (cont.)

Large Magellanic Cloud Cepheid Photometry

No.	P(days)	log P	V	U-B	B-V	V-R	V-I	J	H	K
ROB 22	4.67	0.669	15.55		0.70					
HV 12869	4.50	0.653	15.06		0.62					
HV 12720	4.32	0.635	15.74		0.63					
ROB 9	3.71	0.569	15.80		0.58			14.55	14.22	14.11
HV 6022	3.65	0.562						13.78	13.54	13.52
HV 12747	3.60	0.556	15.76		0.56			14.59	14.27	14.17
								14.56	14.27	14.18
HV 12765	3.43	0.535	15.29		0.57			14.11	13.81	13.79
ROB 25	3.38	0.529	16.03		0.60					
HV 6089	3.21	0.507						13.60	13.29	13.25
HV 2353	3.11	0.492	15.37		0.53					
HV 5672	3.06	0.486						14.11	13.85	13.85
HV 12225	3.01	0.478						14.89	14.60	14.48
								14.96	14.64	14.52
ROB 24	2.69	0.429	16.22		0.51					
HV 5541	2.60	0.415						14.93	14.60	14.45
								14.88	14.62	14.48
ROB 44	2.56	0.408	16.36		0.58					

Table 2

Modern Observations of LMC Cepheids

	Description of Data	Reference
(1)	Photographic (BV) photometry, periods and identifications for 41 Cepheids	Wooley et al. (1962)
(2)	Photoelectric (BV) photometry and periods for 13 Cepheids.	Gascoigne and Kron (1965)
(3)	Identification charts and periods for ∿ 600 Cepheids.	Hodge and Wright (1967)
(4)	Photoelectric (BV) photometry and periods for 9 Cepheids.	Gascoigne (1969)
(5)	Random-phase (BVRI) photoelectric photometry of 2 Cepheids: HV 821 and HV 829.	Mendoza (1970)
(6)	Near-infrared (JHK) photometry of HV 883	Glass (1974)
(7)	Photoelectric (UBV) photometry of 22 Cepheids.	Madore (1975)
(8)	Photographic (BV) photometry of 119 Cepheids.	Connolly (1975)
(9)	Photoelectric (UBVRI) photometry of 11 Cepheids.	Eggen (1977)
(10)	Photographic (BV) photometry of 83 Cepheids.	Butler (1978)
(11)	Photoelectric (BV) averaged photometry for 17 Cepheids for a tilt measurement.	Gascoigne and Shobbrook (1978)
(12)	Photoelectric (UBVI) photometry of 45 Cepheids.	Martin and Warren (1979)
(13)	Photoelectric (BV) photometry of 7 sinusoidal Cepheids.	Connolly (1980)
(14)	Photoelectric (BVI) photometry of 10 cepheids.	Martin (1980)
(15)	Photoelectric (BVI + DDO) photoelectric photometry of 16 Cepheids.	Dean (1981)
(16)	Photographic (BV) photometry for 213 Cepheids.	Martin et al. (1981)
(17)	Photoelectric (BV) photometry for 10 short-period Cepheids.	Martin (1981)
(18)	Photoelectric (Washington) Photometry of 40 Cepheids.	Harris (1983)
(19)	Near-infrared (H) photometry for 40 Cepheids.	McGonegal et al. (1982)
(20)	Photographic (UBVR) photometry for 165 Cepheids.	Wayman, Stift and Butler (1984)
(21)	Photoelectric (BVRI) photometry of 8 Cepheids.	Madore et al. (1985a)
(22)	Photoelectric (BVRI) and near-infrared (JHK) photometry of two Leavitt variables.	Grieve, Madore and Welch (1985)

TABLE 3

Small Magellanic Cloud Cepheid Photometry

No.	P(days)	log P	V	U-B	B-V	V-R	V-I	J	H	K
HV 1956	207.5	2.322	12.19		1.30	0.65	1.20	10.54	10.02	09.83
HV 821	127.6	2.106	11.94	0.79	1.05	0.54	1.04	10.56	10.13	10.00
								10.28	09.90	09.76
HV 829	85.92	1.934	11.91	0.60	0.85	0.46	0.89	10.54	10.07	09.97
								10.40	10.06	09.96
HV 834	73.41	1.866	12.21	0.55	0.87	0.46	0.89	10.89	10.54	10.45
								10.68	10.33	10.19
HV 11157	69.06	1.839	12.94	0.80	1.10	0.56	1.07	11.35	10.86	10.73
								11.12	10.69	10.58
HV 824	65.84	1.818	12.37		0.88	0.46	0.91	11.05	10.58	10.51
								10.85	10.41	10.31
HV 1877	49.80	1.697	13.18	0.47	1.02	0.51	0.99			
HV 837	42.71	1.631	13.23	0.62	0.93	0.49	0.95	11.55	11.17	11.11
								11.72	11.25	11.18
HV 2195	41.80	1.621	13.00	0.61	0.81	0.44	0.85	11.49	11.16	11.11
								11.61	11.23	11.14
HV 11182	39.19	1.593	13.70	0.93	1.04	0.52	1.02	11.88	11.42	11.34
								12.05	11.61	11.55
HV 2231	36.68	1.564	13.52		0.98	0.53	1.00			
								11.83	11.40	11.30
HV 2064	33.68	1.527	13.73	0.63	0.91	0.49	0.96			
								12.37	11.87	11.82
HV 865	33.33	1.523	13.21		0.73	0.42	0.83			
								11.85	11.52	11.41
HV 1636	32.68	1.514	13.84		0.70	0.45	0.91			
HV 10357	32.03	1.505	14.02		0.88					

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TABLE 3 (cont.)

Small Magellanic Cloud Cepheid Photometry

No.	P(days)	log P	V	U-B	B-V	V-R	V-I	J	H	K
HV 840	33.04	1.519	13.58		0.87	0.49	0.94			
HV 1636	32.68	1.514	13.81		0.70	0.45	0.90			
HV 823	31.93	1.504	13.77	0.67	0.96	0.51	0.97	12.32	11.86	11.76
								12.15	11.71	11.67
HV 1369	30.93	1.490	14.42		0.66					
HV 1451	30.08	1.478	14.01		1.05					
HV 863	28.96	1.462	13.34		0.77	0.43	0.84			
HV 1967	28.94	1.461	13.63		0.78					
HV 819	28.44	1.454	14.05	0.60	0.86					
HV 1501	27.41	1.438	14.04		0.83					
HV 847	27.07	1.432	13.92		0.86	0.48	0.93			
HV 2205	25.43	1.405	14.07		0.87	0.47	0.92			
HV 1430	23.98	1.380	14.30		0.86	0.50	0.95			
HV 2209	22.64	1.355	13.55	0.34	0.64	0.38	0.74	12.15	11.85	11.80
								12.27	11.91	11.85
HV 1522	22.15	1.345	14.36		0.93					
HV 11211	21.39	1.330	13.84		0.83	0.46	0.90			

TABLE 3 (cont.)

Small Magellanic Cloud Cepheid Photometry

No.	P(days)	log P	V	U-B	B-V	V-R	V-I	J	H	K
HV 1543	20.48	1.311	14.78		0.90					
HV 817	18.90	1.276	13.85		0.65	0.38	0.77	12.76	12.37	12.28
								12.60	12.24	12.18
HV 1884	18.11	1.258	14.47		0.92	0.48	0.92			
HV 1342	17.94	1.254	14.21	0.36	0.59	0.35	0.72	13.06	12.71	12.63
								12.97	12.64	12.57
HV 10386	17.74	1.249	14.23		0.86		0.93			
HV 1925	17.20	1.236	13.98	0.29	0.62			12.83	12.42	12.35
								12.68	12.29	12.23
HV 822	16.74	1.224	14.52	0.56	0.83			13.04	12.56	12.51
								13.22	12.71	12.64
HV 1954	16.69	1.223	13.84	0.38	0.62	0.38	0.74	12.73	12.31	12.24
								12.82	12.41	12.34
HV 11210	16.43	1.216	14.42		0.87	0.49	0.95			
HV 1787	16.20	1.210	14.27		0.78		0.85			
HV 854	15.97	1.203	14.25		0.65	0.38	0.77			
HV 1328	15.85	1.200	14.13		0.61			12.89	12.54	12.52
								13.07	12.66	12.62
HV 1482	15.82	1.199	14.88		0.76					
HV 1560	15.51	1.191	14.79		0.98					
HV 1442	15.29	1.184	14.81		0.80					

TABLE 3 (cont.)

Small Magellanic Cloud Cepheid Photometry

No.	P(days)	log P	V	U-B	B-V	V-R	V-I	J	H	K
HV 2233	15.17	1.181	13.94		0.61	0.38	0.72			
HV 843	14.71	1.168	15.02		0.93					
HV 1695	14.60	1.164	14.71		0.75	0.48	0.92			
HV 2088	14.58	1.164	14.66		0.79	0.44	0.86			
HV 1579	14.57	1.164	14.43		0.53					
HV 1335	14.38	1.158	14.77		0.69	0.40	0.81			
HV 1933	13.78	1.139	14.24		0.57					
HV 1326	13.72	1.137	14.88		0.76					
HV 1438	13.65	1.135	15.42		0.71					
HV 827	13.46	1.129	14.49		0.60			13.04 12.96	12.79 12.70	12.76 12.68
HV 2189	13.46	1.129	14.50		0.68					
HV 2202	13.19	1.120	14.41		0.70	0.40	0.79			
HV 2225	13.15	1.118	14.78		0.83	0.46	0.92			
HV 1873	12.94	1.112	14.88		0.73	0.42	0.84			
HV 1744	12.62	1.101	14.56		0.63	0.39	0.76			

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TABLE 3 (cont.)

Small Magellanic Cloud Cepheid Photometry

No.	P(days)	log P	V	U-B	B-V	V-R	V-I	J	H	K
HV 1484	9.00	0.954	14.41		0.96					
HV 2103	8.98	0.951	15.12		0.65					
HV 1338	8.50	0.929	15.16		0.49	0.31	0.63			
HV 1437	8.38	0.923	15.50		0.50					
HV 11112	6.70	0.826						14.46	14.14	14.05
								14.54	14.16	14.06
HV 1400	6.65	0.823						14.08	13.84	13.67
								14.11	13.83	13.66
HV 1492	6.30	0.799						13.99	13.61	13.60
								14.06	13.69	13.68
HV 1425	4.55	0.658						14.47	14.38	14.24
								14.63	14.50	14.37
HV 214	4.21	0.624						14.52	14.32	14.29
								14.62	14.42	14.37
HV 11113	3.21	0.507						15.19	14.90	14.84
								15.31	14.95	14.88
HV 11216	3.12	0.494						15.56	15.13	15.23
								15.56	15.11	15.20
HV 1906	3.06	0.486						15.32	15.05	14.93
								15.27	15.06	14.95
HV 1779	1.78	0.251						15.47	15.23	15.00
								15.50	15.24	15.01
HV 1907	1.64	0.216						16.00	15.69	15.75
								16.04	15.75	15.82
HV 1897	1.24	0.094						16.05	15.84	16.64

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TABLE 3 (cont.)

Small Magellanic Cloud Cepheid Photometry

No.	P(days)	log P	V	U-B	B-V	V-R	V-I	J	H	K
HV 2052	12.58	1.100	14.26		0.61					
HV 2230	12.53	1.098	14.67		0.81	0.44	0.83			
HV 2227	12.47	1.096	14.79		0.79	0.45	0.87			
HV 1365	12.41	1.094	15.02		0.70	0.41	0.81			
HV 856	12.16	1.085	14.91		0.72					
HV 1682	12.15	1.085	14.71		0.59					
HV 857	11.98	1.078	14.46		0.59					
HV 1610	11.64	1.066	14.67		0.63	0.37	0.78			
HV 2017	11.41	1.057	14.71		0.71	0.39	0.80			
HV 1630	11.40	1.057	14.99		0.65					
HV 2063	11.17	1.048	14.76		0.72					
HV 6320	10.09	1.004	14.83		0.59	0.37	0.70			
HV 1334	9.45	0.975	14.87		0.59					
HV 836	9.40	0.973	14.79		0.52					
HV 2087	9.16	0.962	15.24		0.71					

Table 4

Modern Observations of SMC Cepheids

	Description of the Data	Reference
(1)	Photographic (BV) photometry of 64 Cepheids (known scale errors).	Arp (1960)
(2)	Photoelectric (BV) photometry of 14 Cepheids.	Gascoigne and Kron (1965)
(3)	Photographic <m>pg photometry and periods for 1151 Cepheids.	Payne-Gaposchkin (1966)
(4)	Photographic (BV) photometry, periods and identifications for 105 Cepheids.	van Genderen (1969a)
(5)	Photoelectric (Walraven) photometry of 12 Cepheids.	van Genderen (1969b)
(6)	Photoelectric (BV) photometry of 12 Cepheids.	Gascoigne (1969)
(7)	Photographic mpg photometry, periods and light curves.	Gaposchkin (1970)
(8)	Photoelectric (UBV) photometry of 17 Cepheids.	Madore (1975)
(9)	Photographic (BV) photometry and periods for 72 Cepheids.	Butler (1976)
(10)	Identification charts for $\sim$1100 Cepheids.	Hodge and Wright (1977)
(11)	Photoelectric (UBVRI) photometry for 11 Cepheids.	Eggen (1977)
(12)	Photoelectric (UBVI) photometry for 25 Cepheids.	Martin and Warren (1979)
(13)	Photographic (BV) photometry for 181 Cepheids.	Martin et al.
(14)	Photoelectric (BV) photometry for 10 short-period Cepheids.	Martin (1981)
(15)	Photoelectric (Walraven) photometry for ** Cepheids.	Pel, van Genderen, and Lub (1981)
(16)	Photoelectric (Washington) photometry of 45 Cepheids.	Harris (1981)
(17)	Photoelectric (Walraven) photometry for HV 1369.	van Genderen (1981)
(18)	Photoelectric (BVRI) photometry for 4 Cepheids.	Madore et al. (1985)

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b) NGC 6822

Beyond the Small Magellanic Cloud, NGC 6822 is the closest gas-rich dwarf galaxy so far discovered to contain Cepheid variables. Unfortunately, NGC 6822 is located in a line of sight that is relatively close to the galactic plane (l = -18). Accordingly, there is considerable contamination of this galaxy's colour-magnitude diagram by galactic foreground stars, and in comparison to other galaxies in the sample, NGC 6822 has a higher and certainly more uncertain obscuration correction. The only systematic search for Cepheids in this galaxy was undertaken by Kayser (1967) using photographic plate material obtained at the prime focus of the Palomar 5m by Chip Arp and Walter Baade. She found periods and light curves in B and V for 13 Cepheids. Her data are given in Table 5. Other than for a few single-phase photoelectric observations of the brightest Cepheids published by Hodge (1977) and by van den Bergh and Humphreys (1979), no modern study of the Cepheids in the optical, using CCD's, for instance, has been undertaken. The large angular size of NGC 6822 is probably the main disincentive for such a study at the present time. However, McAlary et al. (1983) have observed many of the Cepheids in NGC 6822 in the near infrared and they derive a distance modulus of 23.5.

As alluded to above, the most controversial aspect of the study of the distance to NGC 6822 is the reddening and extinction corrections to be adopted for the brightest stars and the Cepheids. The galactic foreground component is probably in excess of E(B-V) = 0.2, and the component internal to the gas-rich dwarf irregular is likely to be of a similar amount and probably patchy in its distribution across the galaxy itself. Multi-colour photometry in addition to the infrared data will be needed to sort out the reddening problem if it is to be solved for explicitly.

TABLE 5

NGC 6822 Cepheid Photometry

No.	P(days)	Log P	<V>	B-V	H
V 13	90.682	1.957	17.75	1.08	14.79
V 7	65.45	1.816	17.56	0.90	15.18
V 25	37.4432	1.573	18.52	0.89	16.24
V 28	34.6672	1.540	18.85	1.02	15.91
V 29	31.835	1.503	18.80	0.75	16.39
V 1	30.4994	1.484	19.02	0.88	
V 3	29.2111	1.466	19.32	0.86	
V 6	21.1450	1.325	19.87	0.50	
V 17	19.2968	1.285	19.22	1.18	16.39
V 21	17.457	1.242	19.76	0.59	17.98
V 4	17.3471	1.239	19.67	0.50	
V 5	13.3550	1.126	19.98	0.68	17.31
V 30	10.9039	1.038	19.73	0.18	17.58

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Table 6

Modern Observations of Cepheids in NGC 6822

	Description of the Data	Reference
(1)	Photographic (BV) photometry, periods and identifications for 13 Cepheids.	Kayser (1967)
(2)	Scattered photoelectric (BV) observations of V7.	Hodge (1977)
(3)	Scattered photoelectric (BV) observations of V7.	van den Bergh and Humphreys (1979)
(4)	Near-infrared (H) photometry of 9 Cepheids.	McAlary, et al. (1984)

c) IC 1613

Like the previous galaxy, IC 1613 is a dwarf irregular member of Local Group. Its Cepheids were marked by Walter Baade and eventually photometered and analyzed by Sandage (1971). The data were obtained again from prime focus plates taken at the Palomar 5m. The disconcerting result of the photographic analysis was that the resulting PL relation can be ambiguously interpreted. As pointed out by Sandage (1971), the slope of the blue PL relation for the Cepheids in IC 1613, taken at face value, is significantly different from the slope of the relation found for the Magellanic Clouds, say. Baade saw this as indicating trouble for the universality hypothesis; however Sandage quite rightly pointed out that the observed PL relation is sufficiently wide in magnitude at any given period (i.e., B $\sim$ 1.5 mag at fixed log P), that small number statistics, systematic population effects across the strip, or the preferential selection of only the brightest Cepheids at short period could result in an apparently different slope to the PL relation despite the stars being drawn from identical instability strips. That is, the Cepheids may still obey the same Period-Luminosity-Colour relation while not necessarily being representative of the full dimensions of the instability strip. Unfortunately no colour data for these Cepheids was available to test this sample.

An alternative interpretation of the photographic data was offered by McAlary, Madore and Davis (1984) after they obtained near-infrared data for many of the same Cepheids in IC 1613. The infrared data is entirely consistent with the PL relations derived for other Local Group galaxies. Therefore, either the effects that lead to a discrepancy in the blue are diminished in the infrared, or possibly the optical data is suffering from a slight magnitude scale error in the photometry, in the sense that the photographic magnitudes are systematically too bright at the faint end. A scale error in the photographic photometry is also suggested by an analysis of the stellar luminosity function for IC 1613 which is apparently too steep compared to all other galaxies studied to date (Freedman 1984a).

The published data for the Cepheids are given in Table 7. The distance to IC 1613 based on the near-infrared data is 24.3.

TABLE 7

IC 1613 Cepheid Photometry

No.		P(days)	Log P	<B>	H
V	22	146.35	2.166	19.07	15.47
V	20	41.953	1.622	19.86	16.66
V	39	28.720	1.458	19:3	16.19
V	11	25.7719	1.411	20.47	17.04
V	2	23.4611	1.370	20.30	17.69
V	18	16.4353	1.216	20.89	
V	37	12.4140	1.084	20.87	
V	16	10.43584	1.019	20.66	
V	6	9.43048	0.974	21.04	18.77
V	25	9.2112	0.960	20.67	18.62
V	34	8.47833	0.928	21.12	
V	24	6.74350	0.829	21.08	
V	27	6.66043	0.820	21.16	18.50
V	26	5.81614	0.765	21.49	
V	17	5.73687	0.759	21.21	19.21
V	1	5.59210	0.748	21.12	
V	9	5.57738	0.746	21.37	
V	14	5.14450	0.711	21.15	
V	13	4.84448	0.685	21.37	
V	12	4.28604	0.632	21.63	
V	30	4.26963	0.630	21.64	19.22
V	15	4.22744	0.626	21.33	
V	10	4.06529	0.609	21.31	
V	3	3.96789	0.599	21.61	
V	29	2.869059	0.458	21.75	

TABLE 8

Modern Observations of Cepheids in IC 1613

	Description	Reference
(1)	Photographic (B) photometry, periods and identifications for 25 Cepheids.	Sandage (1971)
(2)	Near-infrared (H) photometry of 10 Cepheids.	McAlary, Madore and Davis (1984)

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d) M33

This galaxy was first studied for its variable star content by Hubble (1926) who discovered 35 Cepheids in the nuclear regions of this galaxy. The remarkable history of the finder charts for Hubble's comparison stars is given by Sandage (1983) who recently made a first transformation of the old photographic data to the modern B system. As can be seen in Sandage's Figure 6 the corrections found by him are enormous, amounting to 2.5 mag at B ∿ 22. Considering the difficulty of doing eye photometry on variable background plates it should not be surprising that subsequent studies, using linear detectors find that convergence has not yet been reached on the final magnitudes for these stars (see Freedman 1984b).

TABLE 9

M33 Cepheid Photometry

No.	P(days)	Log P	<B>	H
H 10	69.5	1.842	20.8	16.32
H 19	54.706	1.733	19.9	15.81
H 30	46.03	1.663	20.6	17.28
H 3	41.68	1.620	20.7	16.79
B 1	37.6179	1.575	20.2	
H 31	37.33	1.572	20.7	
H 29	36.31	1.560	21.0	
H 20	35.95	1.556	20.	
H 36	35.80	1.554	20.6	
H 18	34.00	1.531	20.7	
H 35	30.5094	1.484	20.7	16.88
H 42	30.34	1.482	20.7	
H 44	30.123	1.479	21.3	16.92
H 4	27.366	1.437	20.8	
H 7	26.556	1.424	21.0	16.59
G 6	26.3218	1.420	20.8	
H 38	25.04	1.399	20.4	17.03
H 11	23.43	1.370	21.1	
H 17	23.297	1.367	21.4	17.44
H 26	23.258	1.367	21.8	
H 27	22.448	1.351	21.2	
H 34	22.16	1.346	21.1	18.34
H 22	21.916	1.341	21.4	
H 12	21.681	1.336	21.1	

TABLE 9 (cont.)

M33 Cepheid Photometry

No.	P(days)	Log P	<B>	H
F 8	21.2764	1.328	21.3	17.92
H 33	20.50	1.312	21.7	
H 43	20.166	1.305	21.7	
H 9	18.90	1.276	21.1	
H 28	18.58	1.269	21.8	
F 12	18.4823	1.267	20.6	18.35
F 9	18.0955	1.258	21.4	
H 41	17.98	1.255	21.1	
H 37	17.602	1.246	21.4	
G 14	17.5576	1.244	21.8	18.12
H 16	17.50	1.243	21.2	
H 39	16.166	1.209	21.2	17.18
H 5	14.60	1.164	21.2	
H 23	13.564	1.132	21.3	
H 25	13.438	1.128	21.7	
G 4	13.0022	1.114	20.8	17.52
H 40	12.922	1.111	21.4	
H 24	12.894	1.110	21.4	
E 14	12.8247	1.108	21.4	
G 5	8.7849	0.944	21.4	
D 54	8.7415	0.942	21.3	
A 1	8.5406	0.931	21.6	
B 8	3.2325	0.510	22.2	

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As a modern photographic check on the distance to M33, Sandage and Carlson (1983) obtained new plate material and discovered new Cepheids in the less crowded, relatively clearer regions in the outer spiral arms of M33. They found 35 new Cepheids. The corrected Hubble data yielded an apparent blue distance modulus to M33 of 25.48, while the Sandage-Carlson data gave a slightly lower value of 25.28. This difference could be indicating systematic shifts in the zero points of the two independent data sets, differences in internal reddening (uncorrected for in the Sandage analysis) between the inner and outer samples of Cepheids, or simply a reflection of the uncertainty inherent in working with small data sets.

Two other studies of the Cepheids in M33 indicate that reddening internal to the parent galaxy itself is important. The first is the CCD multi-colour PL relations for the M33 Cepheids discussed by Freedman (1984b) and the second is the near-infrared data analysed by Madore et al. (1985). Both sets of linear-detector data indicate considerable reddening along the line of sight, amounting to $A_V \sim 0.6$ mag. with a derived true distance modulus of 24.1 as compared to Sandage's preferred modulus of 25.3. The latter modulus, it must be remarked is an apparent modulus, dependent upon a weighted average of the two photographic studies and a much different adopted distance modulus for the Magellanic Clouds, compared to the linear detector studies.

Table 10

Modern Observations of Cepheids in M33

	Description of the Data	Reference
(1)	Identifications and periods for 35 Cepheids (known scale errors in the Photometry).	Hubble (1926)
(2)	Identifications and very approximate colours for 5 Cepheids.	van den Bergh, Herbst and Kowal (1975).
(3)	Photoelectrically calibrated photographic B photometry and periods for 13 Cepheids.	Sandage and Carlson (1983).
(4)	Recalibration of Hubble's Argelander step-scale photometry of 35 Cepheids.	Sandage (1983)
(5)	Near-infrared (H) photometry for 15 Cepheids.	Madore et al. (1985).

e) M31

Next in the progression outwards is the Great Nebula in Andromeda, M31. Several exhaustive photographic studies of the stellar content of selected fields along the major axis of M31 have been published by Baade and Swope (1963, 1965) and by Gaposchkin (1962). In Field I 31 Cepheids are identified and have published periods and B light curves. In Field II 31 Cepheids have been found, while in Field III 232 Cepheids are known. Field IV has the distinction of having 20 Cepheids with measured periods and both B and V light curves measured. Field IV is also the region most distant from the nucleus of M31 and its photometry is therefore probably least affected by the unresolved background of the galaxy and possibly it is the least reddened of the four regions also, although considering the scales over which obscuration changes rapidly, this is at best a statistical statement.

No infrared data on the Cepheids in M31 are yet available because of the severe crowding of the candidate objects partially due to the unfavourably high inclination of the plane of the galaxy to the line of sight. Programmes are underway, both using near-infrared aperture techniques and CCD detectors.

The BV photographic data for the Cepheids in Field IV are collected together in Table 11.

TABLE 11

M31 Cepheid Photometry (Field IV)

No.	P(days)	Log P	<V>	B-V
V 15	21.263	1.328	19.80	0.95
V 31	13.336	1.125	19.81	0.66
V 30	12.878	1.110	20.38	1.05
V 5	12.840	1.109	20.35	1.01
V 3	12.714	1.104	20.38	0.91
V 8	9.643	0.984	20.37	0.74
V 9	8.508	0.930	20.55	0.76
V 17	6.732	0.828	20.83	1.01
V 2	4.368	0.640	21.24	0.59
V 13	3.803	0.580	21.72	0.86
V 46	3.711	0.580	22.15	0.93
V 36	3.593	0.555	21.74	0.78
V 48	3.403	0.532	22.02	0.73
V 21	3.348	0.525	21.64	0.63
V 10	3.043	0.483	21.70	0.60
V 11	2.978	0.474	21.09	0.59
V 27	2.593	0.414	21.68	0.71

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Table 12

Modern Observations of Cepheids in M31

	Description of the Data		Reference
(1)	Field I:	Photographic (B) photometry, periods and identifications for 31 Cepheids.	Baade and Swope (1965)
(2)	Field II:	Photographic (B) photometry, periods and identifications (?) for 131 Cepheids.	Gaposchkin (1962)
(3)	Field III:	Photographic (B) photometry, periods and identifications for 232 Cepheids.	Baade and Swope (1965)
(4)	Field IV:	Photographic (BV) photometry, periods and identifications for 20 Cepheids.	Baade and Swope (1963)

f) Sextans A

Located somewhat beyond the canonical limits of the Local Group is the dwarf irregular galaxy Sextans A. This galaxy has been the object of two recent studies: The first was a photographic study by Sandage and Carlson (1982) who discovered 8 variables and derived light curves and periods for 5 of them that appear to be Cepheids. The second study was conducted by Hoessel, Schommer, and Danielson (1983) using CCD detectors, and was primarily interested in the general stellar content of the system, although some of the brighter Cepheids were also measured.

TABLE 13

Sextans A Cepheid Photometry

No.	P(days)	Log P	B(med)
V 28	25.4370	1.405	21.12
V 3	21.2115	1.327	20.88
V 25	18.5590	1.269	21.43
V 1	15.5522	1.192	21.62
V 24	10.1791	1.008	21.57

TABLE 14

NGC 3109 Cepheid Photometry

No.	P(days)	log P	V	B-V
V 1	65.	1.81	20.54	0.94
V 2	46.	1.66	20.74	0.84
V 3			20.94	0.66

Table 15

Modern Observations of Cepheids in Nearby Dwarf Galaxies

	Description of the Data	Reference
	(a) WLM	
(1)	22 variables announced	Sandage (1979)
	(b) Sextans A	
(1)	Photographic (B) photometry of 5 Cepheids: 3 other variables identified.	Sandage and Carlson (1982)
	(c) Sextans B	
(1)	8 variables announced.	Sandage (1979)
	(d) NGC 3109	
(1)	15 certain variables announced.	Sandage (1979)
(2)	Photographic (BV) photometry of 3 Cepheids. periods for 2.	Demers (1984)

g) NGC 300

Recently, Graham (1984) has reported the results of a photographic study of the Cepheids in NGC 300 begun by him and Malcolm Smith some ten years ago. There are now 18 Cepheids with periods known in NGC 300, one of the closest members of the South Polar (Sculptor) Group of galaxies. The plates, gathered by a number of observers using the CTIO 4m, were obtained in B and V but the photometry is only accurate to 0.1 mag. so the colours are at best indicative. Graham makes his comparison directly with the Magellanic Cloud PL relation and derives two distance moduli $(m-M)_B = 26.14$ and $(m-M)_V = 26.04$, which he averages to give a ture distance modulus of 26.09. The distance so derived assumes that the average internal extinctions suffered by Cepheids in NGC 300 and the LMC cancel. Furthermore the fit assumed by Graham is largely determined by the shortest-period (faintest) Cepheids which have the least certain calibration; slightly larger apparent distance moduli would result from fits to the brightest Cepheids alone.

The photographic data are gathered together in Table 16. To date no near-infrared or CCD photometry of these Cepheids is published but observing programmes are underway to remedy both of these shortcomings.

TABLE 16

NGC 300 Cepheid Photometry

No.	P(days)	Log P	V	B
V 24	126.9	2.103	20.9	20.0
V 18	94.35	1.975	20.9	19.9
V 12	89.40	1.951	20.9	19.9
V 3	56.52	1.752	21.1	20.3
V 32	52.80	1.723	21.2	20.3
V 8	43.35	1.637	21.8	20.6
V 27	34.90	1.543	21.6	20.7
V 13	34.02	1.532	21.4	20.4
V 10	25.00	1.398	21.9	21.0
V 33	24.26	1.385	21.7	21.0
V 28	23.59	1.373	22.1	21.3
V 29	23.43	1.370	21.8	20.9
V 22	20.64	1.315	22.3	21.3
V 9	18.21	1.260	21.6	20.9
V 2	17.84	1.251	21.9	21.2
V 25	16.19	1.209	22.0	20.9
V 26	15.60	1.193	21.9	21.0
V 21	9.67	0.985	22.4	21.4

h) NGC 2403

The late-type spiral NGC 2403 has long been one of the most important galaxies to have its stellar content investigated in detail. Tammann and Sandage (1968) published the results of their extensive study of the resolved population of stars, including photometry of some 17 Cepheids observed primarily near maximum light. The study, done photographically, was at the leading edge of what the best detectors and the largest telescope in the world could produce at that time. Because the Cepheids in NGC 2403 could only be detected near to maximum light (i.e., close to the plate limit) the photometry, (especially in the visual band pass, where few plates, of brighter limiting magnitude were obtained) has been the subject of much discussion and re-interpretation (Madore 1976, Hanes 1982, McCall 1984).

Because the colours of many of the Cepheids in the Tammann and Sandage (1968) study are found to be significantly redder that their galactic counterparts there has been cause for concern, ranging from suggestions that the Cepheids are intrinsically different, to the possibility that they are reddened and obscured, to the final and reluctantly offered

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possibility that the photometry is in error. The photometry is being checked with CCD detectors by the Toronto Group using the facilities of KPNO and CFHT. However, a complementary study has already been completed which indicates that the original blue photographic distance modulus is a slight underestimate of the true distance modulus. For the Cepheids in NGC 2403 the blue data and the modified J-band near-infrared photometry (McAlary and Madore 1984) are reasonably in accord. Since the near-infrared photometry will provide a close approximation to the true modulus it now appears unlikely that the red colour of the Cepheids is due to absorption. The anomalous colours are probably due to errors in the visual photographic photometry, but until such time as the results of the CCD survey are in, the remote possibility of intrinsic differences still exists, although now with diminishing probability.

The importance of NGC 2403 to the distance scale cannot be over-stated. As an assumed member of the M81 Group its distance ties in a large number of other 'calibrating galaxies', by association. Of course if the distance to NGC 2403 is in error, or if it is not a member of the M81 Group, or if the Group has a large back-to-front depth along the line of sight then the calibration based on its association will be systematically in error at that level.

The published BV data for the Cepheids in NGC 2403 as observed at maximum light, are collected in Table 17.

TABLE 17

NGC 2403 Cepheid Photometry

No.	P(days)	Log P	B(max)	V(max)	J
V 3	87.48	1.942	21.97	20.68	19.43
V 19	81.493	1.911	21.91	20.64	20.08
V 46	58.156	1.765	22.31	21.25	20.09
V 33	56.246	1.750	22.19	21.11	20.95
V 25	47.110	1.673	21.24	20.7	
V 54	47.058	1.673	22.87	21:60	
V 5	46.460	1.667	21.55	21.00	
V 21	39.506	1.597	22.67	21:50	21.90
V 1	39.374	1.595	22.02	21.36	
V 4	38.306	1.583	22.38	21.20	
V 34	37.742	1.577	22.62	21:52	
V 8	34.354	1.536	22.01	21.45	
V 15	33.558	1.526	21.98	21.15	
V 29	32.992	1.518	21.41	21.20	
V 6	20.260	1.481	22.12	21.49	
V 40	20.840	1.319	22:70	21:80	
V 42	20.230	1.306	22:70	22:70	

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Table 18

Modern Observations of Cepheids in NGC 2403

	Description of the Data	Reference
(1)	Phtographic (BV) maximum-light photometry for 17 Cepheids.	Tammann and Sandage (1968)
(2)	Near-infrared (J) photometry of 5 Cepheids.	McAlary and Madore (1984)

i) M81

The first indication that the M81 Group might be more widely distributed than was first hoped, came from Sandage (1984) who discusses the resolved stellar population of M81 itself and concludes that NGC 2403 and M81 are separated in distance modulus by about 0.9 mag, with M81 being the more distant. The original reason for not attributing the difference in the resolution of the brightest stars in the two systems as being due to a distance effect, was that the two galaxies are of different morphological type; M81 being of earlier type than NGC 2403 and certainly less active in star formation at the present epoch.

Cepheids are known to exist in M81. Baade (1963) mentions knowing of at least one, and Sandage (1984) has found several with periods he estimates to be around thirty days. More details than that are not yet published although it is certain that ground-based photometry of these stars will not be easy due to the intense crowding problems in the filamentary arms of M81, the less favourable inclination of the galaxy to our line of sight and the promise that the Cepheids are fainter than those in NGC 2403. Several independent CCD surveys of M81 are underway by Cohen, Freedman and Madore.

j) M101

The distance to M101 is at best controversial. This uncertainty will probably persist until Cepheids are found in this galaxy. Sandage and Tammann (1974) have studied the stellar content of M101 in detail and find no cepheid candidates brighter than B $\sim$ 22.5 mag. From this and other lines of evidence they conclude that the distance to M101 is in excess of 29.3. On the other hand Humphreys and Strom (1983) claim a distance modulus of 28.9 for M101 based on their discovery and photometry of red supergiants in M101. In either case the Cepheids should be accessible to modern detectors on large ground-based reflectors. Both Illingworth and Aaronson at KPNO as well as Freedman and Madore at the CFHT are undertaking to find the Cepheids in selected regions of this galaxy. The results are eagerly awaited.

Table 19

Modern Observations of Cepheids in the Most Distant Systems

	Description of the Data	Reference
	(a) M81	
(1)	One Cepheid reported.	Baade (1963)
(2)	37 variables announced, periods for 3 Cepheids.	Sandage (1984)
	(b) M101	
(1)	No Cepheids confirmed to Bmax = 22.5 V7 is possibly a Cepheid.	Sandage and Tammann (1974)

VI. The Next Step

All of the known samples of Cepheids in external galaxies are being re-observed in the near infrared in order to put the Cepheid distance scale on a homogeneous basis. The data available to date and the published results for each of the galaxies surveyed are now discussed in tern. It is anticipated that within the new year or two, and certainly before Space Telescope is launched, that all of the galaxies will be surveyed in the near-infrared and re-worked at the shorter wavelengths using ground-based CCD detectors. The combination of new linear-detector data and a broad spectral range of coverage should allow a refreshed discussion of the precision with which Cepheids can continue to be the principal tool in establishing the distances to nearby galaxies. From all accounts the future role for Cepheids in the extragalactic distance scale looks bright.

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