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First Results from HIPPARCOS Trigonometrical Parallaxes of Mira-type Variables *

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ABSTRACT

HIPPARCOS trigonometrical parallaxes are given for 16 pre-selected Mira variables. Linear diameters are derived for 8 oxygen-rich Miras with known angular diameters. Comparison with pulsation theory shows that two of them (both with periods over 400 day) are fundamental pulsators, the others (all with periods less than 400 day) pulsate in an overtone. The Mira PL relations in M_K and M_{bol} are calibrated for oxygen-rich overtone pulsators adopting slopes for these relations from LMC data. A mean LMC distance modulus of 18.54 is derived; this is very close to that of 18.57 derived from the Cepheids. The uncertainty in the value derived from the Miras is estimated to be less than 0.2 mag. The absolute magnitude of the only carbon-rich Mira in the sample, R Lep (period of 427 day), indicates that it is a fundamental pulsator. Other stars discussed individually are: the symbiotic Mira, R Aqr; the double-period Mira, R Cen; and, two Miras with decreasing periods, R Aql and R Hya.

Key words:
Astrometry - Stars:distances - Stars:variable - Magellanic Clouds - Stars: fundamental parameters - Distance scale.

1 INTRODUCTION AND OBSERVATIONS

Mira variables are of importance in astrophysics as pulsating stars undergoing rapid mass-loss at the tip of the Asymptotic Giant Branch (AGB). Furthermore, Miras in the Large Magellanic Cloud show a narrow period-luminosity (PL) relation in the infrared (Feast et al. 1989) suggesting that these variables should be important galactic and extragalactic distance indicators. In this paper we use the initial release of HIPPARCOS data to derive a zero point for the Galactic Mira PL relation as well as to discuss the pulsation mode of Miras and other issues related to these stars.

The 16 Miras discussed in this paper are listed in Table 1. They were chosen in 1992 as being sufficiently bright at K (2.2μm) that, on the basis of the PL relation and an adopted (Cepheid) distance to the LMC, one would expect them to have significant HIPPARCOS trigonometrical parallaxes. The discussions of the present paper should thus be largely free of problems associated with data sets chosen according to observed parallaxes. Of the 16 stars selected, 11 are apparently normal oxygen-rich Miras (10 of spectral type M and one, χ Cyg, of spectral type S). Two others (R Hya and R Aql) are oxygen-rich Miras with slowly decreasing periods. This may indicate that they are undergoing helium-shell flashes (Wood & Zarro 1981). R Cen is an oxygen-rich Mira which is unusual in having alternating deep and shallow minima in visual light. R Lep is a carbon-rich Mira which undergoes periods of dust obscuration (see Whitelock 1996) and R Aqr is an oxygen-rich Mira in a symbiotic system.

A full discussion of the HIPPARCOS mission and the derivation of the trigonometrical parallaxes is given in the HIPPARCOS catalogue (ESA 1997). The parallaxes (π) of the programme stars are listed in Table 1 in milli-arcsec

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* Based on data from the HIPPARCOS astrometry satellite

Table 1. Observational Data

Star	π	σ_π	A_V	$\bar{K}_0$	N	$\bar{m}_{bol}$	φ	σ_φ	logP
	(mas)		(mag)			(mag)	(mas)		(P in day)
o Cet	7.79	1.07	0.01	−2.50	98	0.70	33.6	3.5	2.521
R Tri	2.51	1.69	0.14	0.93	9	4.04			2.426
R Hor	3.25	1.08	0.02	−0.94	41	2.22			2.611
R Lep	3.99	0.85	0.08	−0.01	121	3.45			2.630
U Ori	1.52	1.65	0.23	−0.64	50	2.54	18.5	2.6	2.566
R Car	7.84	0.83	0.13	−1.35	77	1.74			2.490
R Leo	9.87	2.07	0.02	−2.55	50	0.69	37.4	2.3	2.491
S Car	2.47	0.63	0.35	1.84	34	4.65			2.175
R Hya	1.62	2.43	0.03	−2.48	51	0.66	28.7	3.3	2.590
R Cen	1.56	0.84	0.21	−0.72	67	2.38			2.737
RR Sco	2.84	1.30	0.20	−0.25	55	2.88			2.449
R Aql	4.73	1.19	0.23	−0.78	45	2.34	17.5	3.7	2.454
χ Cyg	9.43	1.36	0.14	−1.93	11	1.39	28.9	3.0	2.611
T Cep	4.76	0.75	0.11	−1.71	2	1.50	24.3	4.4	2.589
R Aqr	5.07	3.15	0.01	−1.02	120	2.26			2.588
R Cas	9.37	1.10	0.12	−1.80	13	1.40	24.9	2.9	2.633

(mas) together with their standard errors σ_π. Prior to the HIPPARCOS observations there was only one trigonometrical parallax of a Mira variable in the literature which had a small standard error. This was a recent determination for R Leo (8.3 ± 1.0 mas; Gatewood 1992). This latter value is in good agreement with the HIPPARCOS result. In the discussion a slightly weighted mean value (8.81 mas) and a standard error of 1.0 mas have been adopted for R Leo (the weighting was proportional to the reciprocal of the individual standard errors). The accuracies of the zero-point and standard errors of the Hipparcos parallaxes are discussed by Arenou et al. (1995) and Lindegren (1995).

Nearby Miras such as those on our programme have large angular diameters. They may also show elliptical shapes and evidence of an asymmetrical light distribution. For instance, Lattanzi et al. (1996) found that in a broad optical wavelength band R Leo had diameters of 70 ± 2 mas and 78 ± 2 mas along two orthogonal axes; whilst W Hya had an even larger eccentricity. Both stars show some evidence of an asymmetrical light distribution as do some other Miras (see, e.g. Haniff 1995). The cause of these asymmetries is not yet known. They could possibly be due to non-radial pulsations, or to the presence of large spots (perhaps the manifestation of giant convection cells), or perhaps to the influence of close companions. Changes in such an asymmetry might affect the derived parallax either by increasing the standard error of the mean result or by introducing a systematic error, depending on the (unknown) time scale of such changes. We assume that any such effect will add only additional random scatter to the mean results for the set of variables discussed here (see also section 3).

Infrared, JHKL, photometry was obtained for all the programme stars. Most of this photometry was obtained with the 0.75-m reflector at SAAO, Sutherland and is on the current SAAO system (Carter 1990). Table 1 gives the mean values of K after correction for extinction, $\bar{K}_0$, and of the bolometric magnitudes, $\bar{m}_{bol}$. A small amount of earlier data (Catchpole et al. 1979; Whitelock et al. 1983), converted to the current SAAO system has been included in these means. The listed values are the average of maximum and minimum magnitudes. Such means are close to those obtained in other ways (see, e.g. Feast et al. 1989). The adopted values of the visual extinction, A_V, are also given. These values were derived and converted to extinctions at infrared wavelengths in the manner described by Feast et al. (1990). In fact, the absorptions are essentially negligible at infrared wavelengths. The bolometric magnitudes were derived from the JHK photometry in the manner described by Feast et al. (1989). The results should thus be comparable with the data on LMC Miras in that paper. Including the L fluxes makes only very small changes to these values.

In the case of R Cas and T Cep which were observed with the 1.25-m reflector at the southern station of the Sternberg Astronomical Institute in the Crimea, small zero point corrections were applied to bring the observations onto the SAAO system. These corrections were determined using overlapping observations of χ Cyg and R Tri. Generally the infrared light curves have excellent phase coverage (in Table 1, N is the number of sets of JHKL observations used). In the case of U Ori with a period close to one year, a slight extrapolation was necessary to estimate the magnitude at minimum. Although only two observations were obtained of T Cep, the L light curve (Strecker 1973) shows it to have an unusually low infrared amplitude ($\Delta L \sim 0.2$ mag). The estimated values for this star in Table 1 also take into account infrared photometry by Dyck et al. (1974) and Heske (1990).

2 LINEAR RADII OF MIRA VARIABLES

Angular diameters have been determined by Haniff et al. (1995) for eight of the stars on our programme. Because of the great depth of Mira atmospheres these workers corrected their optical observations using stellar models, to obtain an appropriate photospheric diameter. We have used their "E model" angular diameters. That these corrected diameters are satisfactory is shown by the generally good agreement with diameters measured in the infrared (see Feast 1996). Table 1 gives the Haniff et al. corrected angular diameters (ϕ) together with their standard errors (σ_ϕ). The linear radii

Table 2. Derived Quantities

	R	σ_R	M_K	$M_K + 1\sigma$	$M_K - 1\sigma$	M_{bol}	$M_{bol} + 1\sigma$	$M_{bol} - 1\sigma$
	($R_\odot$)					(mag)		
o Cet	464	80	–8.04	–7.76	–8.36	–4.84	–4.56	–5.16
R Tri			–7.07	–5.95	–9.50	–3.96	–2.84	–6.39
R Hor			–8.38	–7.76	–9.26	–5.22	–4.60	–6.10
R Lep			–7.01	–6.59	–7.53	–3.55	–3.13	–4.07
U Ori	1308	*	–9.73	–8.14		–6.55	–4.96	
R Car			–6.88	–6.66	–7.12	–3.79	–3.57	–4.03
R Leo	456	59	–7.83	–7.59	–8.09	–4.59	–4.35	–4.85
S Car			–6.20	–5.70	–6.84	–3.39	–2.89	–4.03
R Hya	1904	**	–11.43	–9.44		–8.29	–6.30	
R Cen			–9.75	–8.82	–11.43	–6.65	–5.72	–8.33
RR Sco			–7.98	–7.17	–9.31	–4.85	–4.04	–6.18
R Aql	398	131	–7.41	–6.92	–8.04	–4.29	–3.80	–4.92
χ Cyg	329	58	–7.06	–6.77	–7.40	–3.74	–3.45	–4.08
T Cep	549	132	–8.32	–8.00	–8.69	–5.11	–4.79	–5.48
R Aqr			–7.50	–6.45	–9.60	–4.22	–3.17	–6.32
R Cas	286	47	–6.94	–6.70	–7.21	–3.74	–3.50	–4.01

* U Ori 1σ lower limit R=539 $R_\odot$
** R Hya 1σ lower limit R=674 $R_\odot$
R Hya 2σ lower limit R=421 $R_\odot$

(R), in solar units, derived by combining these angular diameters with the HIPPARCOS parallaxes, and the adopted mean parallax in the case of R Leo, are given in Table 2. The standard errors of R were computed from the standard errors of both quantities (σ_ϕ and σ_π). The percentage errors in the parallaxes of U Ori and R Hya are such as to make the uncertainties in the derived radii very great. Table 2 gives the one and two σ lower limits to the radii (considering in each case ϕ taken at its one σ lower limit and π at either its one or two σ upper limit). In the case of U Ori, R Leo and *o* Cet infrared angular diameters derived from lunar occultation observations or interferometry are also available (Ridgway et al. 1977; Di Giacomo et al. 1991; Ridgway et al. 1992). We have, however, felt it best to discuss only the Haniff et al. data so that all the diameters are on strictly the same system. Taking the infrared observations into account would not change any of our conclusions.

Figure 1 shows the period-radius relation for these stars. Galactic kinematics (Feast 1963) and other evidence (see, Feast and Whitelock 1987) indicate that Mira variables are low mass objects. The lines in Fig. 1 show the predicted relations for fundamental and for first overtone pulsators with masses of 1.0 and 1.5 solar masses. For the fundamental pulsation solution the equation of Wood (1990) was used;

$$logP = 1.949logR - 0.9logM - 2.07. \qquad (1)$$

Where M is the mass in solar units and P the period in day (Kholopov et al. 1985-7). In the case of the first overtone a standard relation viz;

$$logP = 1.5logR - 0.5logM + logQ \qquad (2)$$

was adopted with Q = 0.04 (similar to values predicted by Fox & Wood (1982)).

There has been a great deal of discussion in the past on the mode of pulsation of Mira variables. Angular diameters together with distances from a PL relation (using an adopted distance to the LMC) have strongly favoured overtone pulsation (see, e.g. Feast 1996). However, the excitation of the characteristic Mira emission spectrum has seemed to require shock phenomena which are only reproduced in models pulsating in the fundamental mode (e.g. Bessell et al. 1996). In a further development, it has been suggested recently (Ya'ari & Tuchman 1996) that the effects of pulsation on the structure of the stars invalidates the relatively simple models employed in predicting the fundamental and overtone lines in Fig.1.

Table 2 and Fig. 1 show that these Miras can be divided into three groups. χ Cyg and R Cas, which are the only variables in the plot with periods over 400 days, lie in the region predicted for fundamental pulsators. In contrast, R Aql, R Leo, *o* Cet, and T Cep lie in the overtone region. The derived radii of U Ori and R Hya are very large; however they also have very large uncertainties. Thus it seems possible that they belong with the other overtone pulsators.

The "E" model angular diameters used here were derived by combining optical observations with stellar models appropriate to overtone pulsation. It is therefore not clear whether they are applicable to χ Cyg and R Cas which we identify as fundamental pulsators. The "D" models of Haniff et al. which are based on fundamental pulsation models would give linear diameters of 374 and 328 solar radii for these two stars, respectively. These agree somewhat less well with the fundamental pulsation predictions in Fig. 1 (being slightly above them) though the difference may not be significant. Furthermore the "D" models are considerably hotter than the "E" models and there is no evidence that χ Cyg or R Cas are hot compared with stars of slightly shorter period. It is not clear therefore that the "D" model is in fact appropriate for these stars. In any case our main conclusion is that the HIPPARCOS parallaxes show that these stars must be pulsating in a different mode from the other stars in Fig. 1 and that this mode is the fundamental. The data tentatively suggest that in the case of both the overtone and the fundamental the theoretical lines are displaced slightly

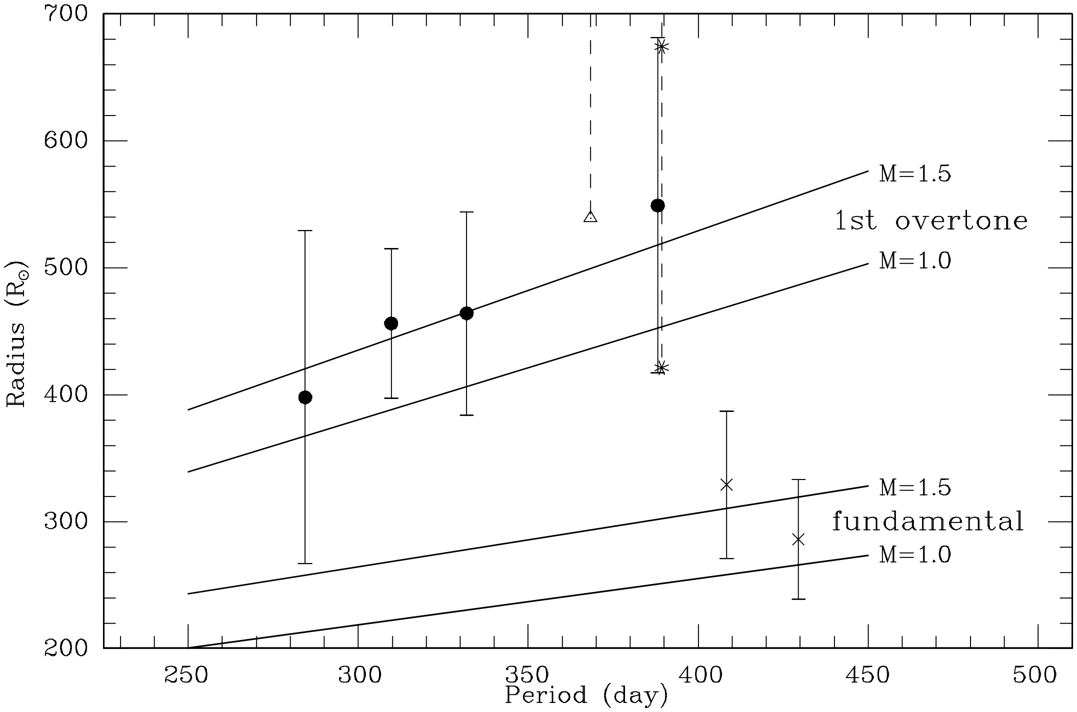

Figure 1. The Period - Radius relation for Mira variables. Filled circles; R Aql, R Leo, *o* Cet, T Cep. Crosses; χ Cyg, R Cas. 1σ error bars are shown. The triangle is the 1σ lower limit for U Ori and the asterisks are the 1σ and 2σ lower limits for R Hya (see text). The lines are those predicted for fundamental and for first overtone pulsation.

downwards with respect to the observations.

These results can then be taken to indicate that most Miras with periods shorter than 400 day are pulsating in an overtone. For periods over 400 day, at least some Miras are pulsating in the fundamental. The fact that the stars fall into the general regions predicted for fundamental and overtone pulsation suggests rather strongly that the relatively simple models used to predict the pulsational behaviour of these stars are satisfactory (at least to a first approximation). It also indicates that the mechanism for exciting the Mira emission spectrum still remains to be understood.

3 THE MIRA PERIOD-LUMINOSITY RELATION

Both oxygen-rich and carbon-rich Miras in the LMC show excellent PL relations in the infrared and in $m_{\rm bol}$ (Feast et al. 1989; Groenewegen & Whitelock 1996). For oxygen-rich Miras the scatter about a mean relation is only 0.13 mag in $\bar{K}_0$ and 0.16 mag in $\bar{m}_{\rm bol}$. Wood (1990) suggested on theoretical grounds that Miras in our Galaxy might be about 0.4 mag fainter in $M_{\rm bol}$ than those in the LMC and this correction has been adopted by a number of workers. However, the theoretical result is not conclusive (Feast 1996) and Whitelock et al. (1994) found that the zero point of the PL relation for oxygen-rich Miras varied little, if at all, between the Galaxy and the LMC. Their evidence came from a comparison of LMC Miras (using an adopted LMC distance) with Miras of known distance in our Galaxy (in metal-rich globular clusters, visual binaries etc.). Furthermore, Wood (1995) found no evidence for a difference in the zero point of the Mira PL relation between the LMC and the SMC. These results suggest that Miras are excellent distance indicators both within our Galaxy and in extragalactic systems. Miras have, in fact, already been used extensively to determine the structure and distance of the Galactic Bulge (e.g. Whitelock et al. 1991; Whitelock & Catchpole 1992; Glass et al. 1995). A fundamental calibration of the zero point of the PL relations is therefore of considerable importance.

Table 2 gives the absolute magnitudes, M_K and $M_{\rm bol}$ of the programme stars together with their standard errors, as derived from the data in Table 1 and the adopted mean parallax of R Leo. These data are plotted in Figs. 2 and 3. The lines are the PL relations from the LMC (Feast et al. 1989) using a commonly adopted distance modulus of the LMC (18.50). Some care is needed in interpreting these figures since Gaussian parallax errors propagate into non-Gaussian errors in absolute magnitudes. However, it is clear that the two Miras that were identified as fundamental pulsators in section 2 (χ Cyg and R Cas) are, as expected, fainter than others of comparable period. We consider these stars and also the non-standard stars, R Aqr, R Cen and R Lep later (see section 4) and base a determination of the PL zero-points on the other eleven (normal) oxygen-rich Miras.

Whilst the data suggest an increase in luminosity with period, they are not sufficient to define the slopes of PL

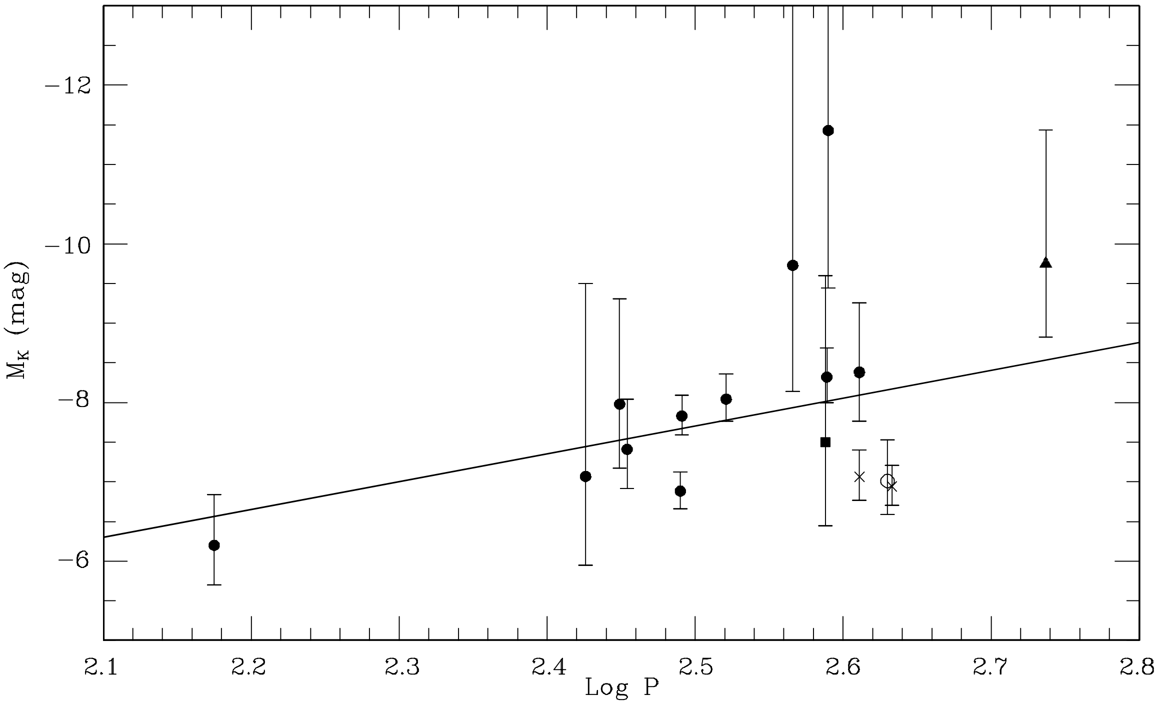

Figure 2. The M_K - log P relation. Open Circle, the C-type Mira R Lep; Filled square, the symbiotic Mira, R Aqr; Filled triangle, the double period Mira, R Cen; Crosses, the fundamental pulsators, χ Cyg and R Cas; Filled circles, other stars. The line is the relation from the LMC with the commonly adopted distance modulus (18.50).

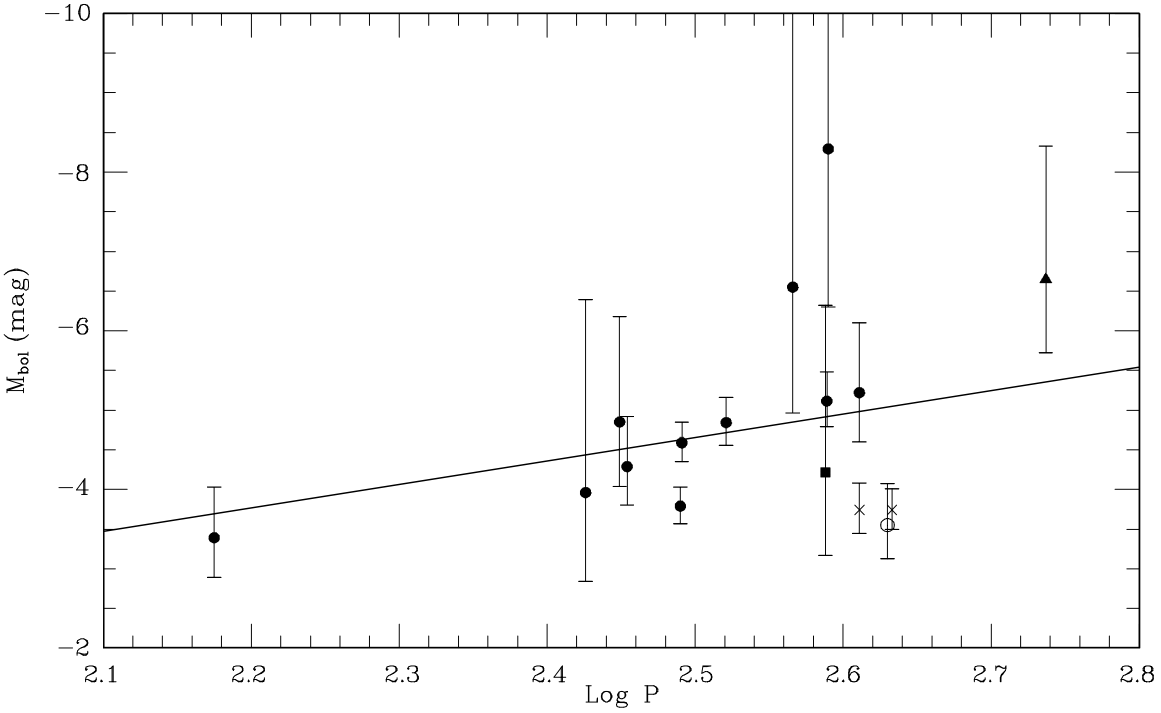

Figure 3. the M_{bol} - log P relation. Symbols as in Fig. 2. The line is the relation from the LMC with the commonly adopted distance modulus (18.50).

relations. The slopes derived for oxygen-rich Miras in the LMC (Feast et al. 1989) have therefore been adopted, viz;

$$M_K = -3.47 logP + \beta_1 \quad (3)$$

and

$$M_{bol} = -3.00 logP + \beta_2. \quad (4)$$

In order to avoid bias, these equations were solved in the form:

$$10^{0.2\beta_1} = 0.010\pi 10^{0.2(3.47logP+K_0)}, \quad (5)$$

$$10^{0.2\beta_2} = 0.010\pi 10^{0.2(3.00logP+m_{bol})}. \quad (6)$$

In principle the derived mean values of $10^{0.2\beta_{\rm n}}$ can be used with the data for LMC Miras to get the mean parallax of the LMC. Since the scatter of the LMC Miras about the PL relations is small, the result is not significantly different from using a value of $\beta_{\rm n}$ derived directly from the mean value of $10^{0.2\beta_{\rm n}}$ to obtain a mean LMC distance modulus. Three sets of means are listed in Table 3: (1) with the parallaxes of the Miras each given unit weight; (2) weighted by the reciprocal of their standard errors; and (3) weighted by the squares of the reciprocals of their standard errors. The latter is the statistically correct solution. The others are given to illustrate the (small) effect of weighting. In each case the corresponding distance modulus of the LMC is given so that these values can be compared with the frequently adopted distance modulus of 18.50 and the current best Cepheid distance modulus, 18.57 ± 0.1 (Feast 1995).

Adopting solution 3, the mean LMC distance modulus is 18.54 and the corresponding values of β are $\beta_1 = 0.94$ and $\beta_2 = 2.81$. The formal uncertainty in these values is $\sim \pm 0.18$. Perhaps the biggest uncertainty is whether R Car differs significantly from the mean. The parallax is $3\sigma_\pi$ different from the value expected from the PL relation. The parallax of R Hya differs from its expected PL value by $2.5\sigma_\pi$ in the opposite sense. Both stars have been retained. The mean parallax residual without regard to sign, as a fraction of each star's σ_π is 1.00 for the 11 calibrating stars (for the K magnitude solution and the adopted value of β_1). The expected (Gaussian) value is 0.80. This indicates that any varying asymmetries in the stellar discs, such as discussed in section 1, cannot have added a large scatter to the parallaxes over and above that reflected in the HIPPARCOS standard errors. It obviously also shows that the observations are compatible with a narrow PL relation such as found in the LMC by Feast et al. (1989).

The adopted Mira distance modulus for the LMC derived from the trigonometrical parallaxes is very close to the current Cepheid distance modulus (18.57). Whilst the agreement to within a few hundredths of a magnitude is no doubt fortuitous, it nevertheless strongly suggests that the distance modulus of the LMC is correctly known to about 0.1 mag. It seems very unlikely that the Mira and Cepheid moduli would agree at this level if either were markedly affected by some effect for which allowance had not been made (e.g. metallicity effects in the Miras).

Table 3. Mira PL zero-points and corresponding LMC distance moduli

	M_K Solutions			$M_{\rm bol}$ Solutions			
Weight	β_1	σ_β	LMC	β_2	σ_β	LMC	N
1 none	0.74	0.26	18.74	2.69	0.24	18.66	11
2 $(1/\sigma_\pi)$	0.83	0.21	18.65	2.80	0.21	18.55	11
3 $(1/\sigma_\pi)^2$	0.88	0.18	18.60	2.88	0.17	18.47	11

It will be noticed in Table 3 that whichever weighting procedure is followed, the distance modulus of the LMC determined from $\rm M_{bol}$ is always about 0.1 mag smaller than that determined from $\rm M_K$. An equivalent effect was already found for Miras in the South Galactic Cap (Whitelock et al. 1994) and for those in the Sgr I field of the Galactic Bulge (Glass et al. 1995) when distances were determined from PL relations with an adopted LMC distance. This result may be connected with colour differences at a given period between Miras in the LMC and those in the Galactic Bulge (Glass et al. 1995) which have been interpreted as metallicity effects (Feast 1996). If, as suggested by Wood (1990), $\rm M_K$ is less sensitive to metallicity effects than $\rm M_{bol}$, it may be more appropriate to adopt an LMC distance modulus from Miras of 18.60 rather than the mean value of 18.54 adopted above.

4 FUNDAMENTAL PULSATORS AND OTHER STARS

The oxygen-rich Miras, χ Cyg and R Cas, which have been identified above as fundamental pulsators present an interesting problem. They can hardly be related to overtone pulsators of about half their periods. These latter stars are generally of earlier spectral type (i.e. hotter). Figure 6a of Reid et al. (1995) shows that there might be a few LMC Miras with $\rm M_K$s and periods similar to χ Cyg and R Cas. Further work is however required to confirm this.

The only carbon-rich Mira in the sample, R Lep, lies with χ Cyg and R Cas below the PL relations in Figs. 2 and 3 and thus also appears to be a fundamental pulsator. This star undergoes periods of heavy circumstellar dust obscuration (see Whitelock 1996). The mean magnitudes given in Table 1, and used for Table 2 and the figures, are values outside such events. Carbon-rich Miras in the LMC follow PL relations at $\rm M_K$ and $\rm M_{bol}$ very close to those of the (overtone) oxygen-rich stars (Feast et al. 1989; Groenewegen & Whitelock 1996).

R Aqr is a particularly interesting oxygen-rich Mira in a symbiotic system which is close enough for the system to be partially resolved (e.g. Paresce & Hack 1994). This Mira also undergoes periods of self-obscuration (Whitelock et al. 1983) during which the star can become up to 1.5 mag fainter than normal at K. The magnitudes given in Table 1 and used for Table 2 and the figures were derived from observations outside such events. Unfortunately the HIPPARCOS parallax does not allow us to distinguish between overtone and fundamental pulsation but it is consistent with the red variable being a normal Mira.

R Cen belongs to a small group of Miras which show alternating deep and shallow minima. In Figs. 2 and 3 it is plotted at its formal (double) period although its relatively early spectral-type and infrared colours suggest that it belongs with stars of half this period (Keenan et al. 1974; Feast et al. 1982). It lies above the PL relation at either the formal period or half this value, but considering the uncertainty of the derived absolute magnitude the difference may not be significant.

The two Miras with slowly decreasing periods (R Aql and R Hya) have been included in the eleven calibrating stars at their latest catalogued periods (Kholopov et al. 1985-7). R Aql lies near the mean PL relations. R Hya differs from them by $2.5\sigma_\pi$ (the largest fractional deviation after R Car). It is doubtful if this deviation should be considered significant and we have used this star with the other calibrators as described in section 3.

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REFERENCES

Arenou F., Lindegren L., Froeschle M., Gomez A. E., Turon C., Perryman M. A. C., Wielen R., 1995, A &A, 304, 52

Bessell M.S., Scholz M., Wood P.R., 1996, A &A, 307, 481

Carter B.S., 1989 MNRAS, 242, 1

Catchpole R.M., Robertson B.S.C., Lloyd Evans T.H.H., Feast M.W., Glass I.S., Carter B.S., 1979, SAAO Circulars, No. 4, p.61

Di Giacomo A., Richichi A., Lisi F., Calamai G., 1991, A &A, 249, 397

Dyck H.M., Lockwood G.W., Capps R.W., 1974, ApJ, 189, 89

ESA, 1997, The Hipparcos Catalogue, ESA SP-1200

Feast M.W., 1963, MNRAS, 125, 367

Feast M.W., 1995, ASP Conf. Ser., 83, 209

Feast M.W., 1996, MNRAS, 278, 11

Feast M.W., Robertson B.S.C., Catchpole R.M., Lloyd Evans T., Glass I.S., Carter B.S., 1982, MNRAS, 201, 439

Feast M.W., Glass I.S., Whitelock P.A., Catchpole R.M., 1989, MNRAS, 241, 375

Feast M.W., Whitelock P.A., 1987 in Kwok S., Pottasch S.R., eds., Late Stages of Stellar Evolution, Reidel, Dordrecht, p.33

Feast M.W., Whitelock P.A., Carter B.S. 1990 MNRAS, 247, 227

Fox M.W., Wood P.R., 1982, ApJ, 259, 198

Gatewood G., 1992, PASP, 104, 23

Glass I.S., Whitelock P.A., Catchpole R.M., Feast M.W., 1995, MNRAS, 273, 383

Groenewegen M.A.T., Whitelock P.A., 1996, MNRAS, 281, 1347

Haniff C., 1995, in ASP Conf. Ser. 83, 270

Haniff C.A., Scholz M., Tuthill P. G., 1995, MNRAS, 276, 640

Heske A., 1990, A &A, 229, 494

Keenan P.C., Garrison R.F., Deutsch A.J., 1974, ApJS, 28, 271

Kholopov P.N. et al., 1985-7 General Catalogue of Variable Stars, Moscow, Nauka publishing house.

Lattanzi M.G., Munari U., Whitelock P.A., Feast M.W., 1996, in preparation

Lindegren L., 1995, A &A, 304, 61

Paresce F., Hack W., 1994, A &A, 287, 154

Reid I.N., Hughes S.M.G., Glass I.S., 1995 MNRAS, 275, 331

Ridgway S.T., Wells D.C., Joyce R.R., 1977, AJ, 82, 414

Ridgway S.T., Benson J.A., Dyck H.M., Townsley L.K., Hermann R. A., 1992, AJ, 104, 2224

Strecker D.W., 1973 PhD Thesis, University of Minnesota

Whitelock P.A., 1996, in IAU Symposium 177, The Carbon Stars, ed. Wing R. Kluwer:Dordrecht, in press

Whitelock P.A., Feast M.W., Catchpole R.M., Carter B.S., Roberts G., 1983, MNRAS, 203, 351

Whitelock P.A., Feast M.W., Catchpole R. M., 1991, MNRAS, 248, 276

Whitelock P.A., Catchpole R.M., 1992 in Blitz L., ed. The Center, Bulge and Disk of the Milky Way, Kluwer. Dordrecht, p. 103

Whitelock P.A., Menzies J.W., Feast M.W., Marang F., Carter B.S., Roberts G., Catchpole R.M., Chapman J., 1994, MNRAS, 267, 711

Wood P.R., 1990, in Mennessier M.O., Omont A., eds., ¿From Miras to Planetary Nebulae, Editions Frontières, Gif-sur-Yvette, p.67

Wood P.R., 1995 in ASP conf. Ser. 83, 127

Wood P.R., Zarro D.M., 1981 ApJ, 247, 247

Ya'ari A., Tuchman Y., 1996, ApJ, 456, 350