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The absolute magnitudes of RR Lyraes from HIPPARCOS parallaxes and proper motions*

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Abstract. We have used HIPPARCOS proper motions and the method of Statistical Parallax to estimate the absolute magnitude of RR Lyrae stars. In addition we used the HIPPARCOS parallax of RR Lyrae itself to determine it's absolute magnitude. These two results are in excellent agreement with each other and give a zero-point for the RR Lyrae M_v,[Fe/H] relation of 0.77±0.15 at [Fe/H]=-1.53. This zero-point is in good agreement with that obtained recently by several groups using Baade-Wesselink methods which, averaged over the results from the different groups, gives $M_v = 0.73\pm0.14$ at [Fe/H]=-1.53. Taking the HIPPARCOS based zero-point and a value of 0.18±0.03 for the slope of the M_v,[Fe/H] relation from the literature we find firstly, the distance modulus of the LMC is 18.26±0.15 and secondly, the mean age of the Globular Clusters is 17.4±3.0 GYrs. These values are compared with recent estimates based on other "standard candles" that have also been calibrated with HIPPARCOS data. It is clear that, in addition to astrophysical problems, there are also problems in the application of HIPPARCOS data that are not yet fully understood.

Key words: stars: variables: RR Lyraes – Galaxy: Globular Clusters – galaxies: Magellanic Clouds

1. Introduction

RR Lyraes are one of the primary distance indicators. Within the Galaxy they are used to determine the distances to the Globular Clusters and hence their ages by matching their Colour-Magnitude diagrams with theoretical isochrones (eg Chaboyer et al. 1996). Since the Globular Clusters are amongst the oldest objects in the Galaxy this sets a lower limit to the age of the Universe. RR Lyraes are also used to determine distances to other Local Group galaxies where they serve as a check on brighter distance indicators, eg Cepheids. They are thus an important step on the path to determining the Hubble Constant (eg Freedman et al. 1997). In combination with a Cosmological Model, the Hubble Constant sets an upper limit to the age of the Universe and a comparison of this age with that of the Globular Clusters provides an important check on several key areas of astronomy and astrophysics (the distance scale, cosmology, stellar structure and evolution, etc.).

For these reasons there is a considerable body of work in the literature on the subject of RR Lyrae absolute magnitudes (see Feast 1997 for a review of this). In the present paper we use HIPPARCOS trigonometric parallaxes to estimate M_v directly (Sect. 3) and HIPPARCOS proper motions to estimate it using the method of Statistical Parallax (Sect. 4). Finally the implications of these results for firstly, the distance to the LMC and secondly, the ages of the Globular Clusters are discussed (Sect. 5) and summarised (Sect. 6). We begin by presenting the basic data (Sect. 2).

2. The data

The data are listed in the Table 1 and described in the Notes thereto. Some further details are given below.

1. **V Photometry and Periods.** HIPPARCOS obtained BV photometry on the Tycho system for the brighter stars and V photometry on the Hipparcos system for all the stars. In order to keep the photometry homogeneous we have used only the Hipparcos photometry. This covers the entire period of the mission (ie Aug'89 - Aug'93) and typically there were around 120 points per star. Table 1 lists the intensity mean V magnitudes on the Johnson system. These have been derived from the Hipparcos photometry as follows. Firstly

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* Table 1, which contains the basic data for the RR Lyraes, is available only at CDS. It may be retrieved via anonymous FTP at cdsarc.u-strasbg.fr (130.79.128.5) or via the Web at http://cdsweb.u-strasbg.fr/Abstract.html

the photometry was converted into fluxes and phased using periods from the GCVS (Kholopov et al. 1985). Using the program PULSAR (Skillen 1985) the period was optimised and this is the period listed in the Table 1. Secondly, the re-phased fluxes were fitted to a Fourier Series, again using the program PULSAR. The order of the fit varied from star to star depending on the quality of the photometry but was typically of order 6. The mean flux so found was then converted back into a magnitude. Finally this magnitude was transformed onto the Johnson system using the relations given by the HIPPARCOS project as a function of the (V-I) colour. Specifically we made the correction $V_J = V_H - X$ where X = 0.09 (RRab Lyraes) and 0.06 (RRc Lyraes). Liu and Janes (1990a) list intensity mean V_J magnitudes for 11 RRab Lyraes and 2 RRc Lyraes and comparing our values with theirs shows a mean difference of 0.003 mags with an rms scatter of 0.007 mags.

2. **Reddenings.** Using the Galactic latitudes and longitudes listed in the GCVS (Kholopov et al. 1985) we estimated E(B-V) values from the Burstein and Heiles (1982) maps. For the low latitude stars not covered by these maps the reddening was estimated by combining the (V-K) colour and [Fe/H] values (from the Table 1) with the intrinsic Period-(V-K)-[Fe/H] relations from Fernley (1993a) and the ratio E(B-V) = 0.35E(V-K) from the same source. Finally, to determine A_v we took a value of R = A_v/E(B-V) = 3.1.
3. **Mode Discrimination.** Simon and Teays (1982) noted that the Fourier component R_{21} clearly discriminates between RRab (fundamental mode) and RRc (overtone mode) Lyraes. As a by-product of the Fourier fitting required to determine the intensity mean magnitudes (Sect. 2.1) we were thus able to separate the RRab and RRc Lyraes. In addition several stars gave a low value for R_{21}, similar to an RRc Lyrae, but their periods were more than 0.50 day, like an RRab type. These stars were V363 Cas, XZ Cet and AR Ser. Simon and Teays similarly found XZ Cet to be unusual and from a more detailed study of it's photometric and spectroscopic parameters suggested it was an Anomalous Cepheid. Since Anomalous Cepheids could be significantly brighter than RR Lyraes we have excluded all three stars from the analysis.
4. **Binaries.** Many of the RR Lyraes now have several estimates of their systemic velocities. Some stars showed more scatter than attributable purely to observational error and probably they are binaries. The stars are: CI And, TY Aps, TV Boo, RU Cet, XZ Cyg, BK Dra, ST Leo, BX Leo RW Tra and TU UMa. Only TU UMa has previously been reported as a binary (Saha and White 1990). Since any companion is likely to be either a low-mass main sequence star or an evolved star the photometric effect will be small and we have retained these stars in the analysis.
5. **Rejected Stars.** Of the 180 stars listed in the HIPPARCOS Input Catalogue as RR Lyraes we have rejected 36 and these are listed and briefy discussed in the Table 1. The remaining 144 stars were used in the analyses described in the following two sections.

3. Trigonometric parallaxes

One star, RR Lyrae itself, has a reasonably well determined parallax, π=4.38$\pm$0.59 mas which is equivalent to σ_π/π=0.13. The remaining stars are at least a magnitude fainter with correspondingly smaller parallaxes and larger errors and values of $\sigma_\pi/\pi \geq 0.30$. These stars are clearly close to the measurement limit of the satellite and van Leeuwen and Evans (1997) have shown that in this case better solutions can be made using the Intermediate Astrometric Data, i.e. the individual position measurements. However, for our dataset no solution was possible (van Leeuwen 1997, Priv.Comm.). It should be noted that the solution for M_v(RR) quoted in van Leeuwen and Evans (1997) is based on a dataset that is different from the present one in several respects. Firstly, their data are raw HIPPARCOS photometry, the magnitudes have not been either dereddened or transformed to the Johnson system. Secondly, they include many stars which we have rejected (see details in the Table 1) and in particular several of these stars are relatively bright, e.g. XZ Cet, V1719 Cyg and NSV5394.

For RR Lyrae itself, using the intensity mean Johnson magnitude, the reddening and the parallax listed in the Table 1 we obtain M_v=0.78$\pm$0.29. RR Lyrae has [Fe/H]=-1.39. The question arises as to whether we need to make Lutz-Kelker corrections to this magnitude (Lutz and Kelker 1973, Hanson 1979). This correction arises when stars are selected according to parallax and compensates for a systematic bias in the sense of the observed parallaxes being overestimated. However our selection of RR Lyrae is not on the basis of its parallax (there are 13 other stars with parallaxes greater than that of RR Lyrae) but on the standard error of the parallax (RR Lyrae has σ_π=0.59 mas whereas all the other stars have $\sigma_\pi \geq 0.9$ mas). Thus no L-K correction is required. In passing we note that given the value of σ_π/π for RR Lyrae and given that our sample of stars has an N$\sim$2 proper motion distribution then from Hanson (1979) the correction would have been only 0.07 mags, in the sense of making M_v brighter.

4. Statistical parallax

Using the data listed in Table 1 (proper motions, V magnitudes, reddenings and radial velocities) and the program described by Hawley et al. (1986) we obtained the solutions shown in Table 2. It is important in the Statistical Parallax method to isolate a dynamically homogeneous sample of stars. In the present context this means separating the Halo and Old Disk components and we have done this by making a cut in metallicity. Based on previous work (eg Layden et al. 1996, Fig 4) it is clear that below [Fe/H] = -1.3 the stars are almost entirely Halo and above [Fe/H] = -0.8 they are almost entirely Old Disk. Unfortunately there are insufficient stars with [Fe/H]$\geq$-0.8 to obtain a useful solution and so we have run instead a metal-rich solution which contains all stars with [Fe/H] $\geq$ -1.3. This sample is therefore not dynamically homogeneous in that it contains a mixture of both Old Disk and Halo stars. Similarly the first sample in Table

Table 2. Absolute magnitudes from statistical parallaxes

Sample	No Stars	[Fe/H]	M_v
All RR Lyraes	144	-1.32	0.76 ± 0.13
Halo RR Lyraes	84	-1.66	0.77 ± 0.17
Metal-Rich RR Lyraes	60	-0.85	0.69 ± 0.21

2, all RR Lyraes, and hence our preferred solution is that for the Halo RR Lyraes.

These results are very close to those from previous studies which used ground based proper motions (Hawley et al. 1986, Layden et al. 1996, Strugnell et al. 1986). We show in Fig.1 a comparison of the HIPPARCOS and ground-based proper motions, where the latter are taken from the paper by Layden et al. (1996) and are primarily from the Lick Northern Proper Motion Survey (Klemola et al. 1987). Whilst the HIPPARCOS errors are smaller, typically 2.2 mas/yr as compared to 5.6 mas/yr for the ground-based data, it can be seen that the overall agreement is good.

5. The M_v, [Fe/H] calibration and implications for the distance scale

Combining the results from Section 3 (the trigonometric parallax of RR Lyrae, which gives M_v=0.78±0.29 at [Fe/H]=-1.39) and Section 4 (the Statistical Parallax solution for 84 Halo RR Lyraes, which gives M_v=0.77±0.17 at [Fe/H]=-1.66) we obtain M_v=0.77±0.15 at [Fe/H]=-1.53. These results give no information about the slope of the M_v,[Fe/H] relation, however this has recently been discussed by Fernley et al. (1997) who estimate a value of 0.18±0.03. Thus we obtain

$$M_v = 0.18 \pm 0.03([Fe/H] + 1.53) + 0.77 \pm 0.15 \quad (1)$$

5.1. Distance to the LMC

We show in Table 3 some recent determinations of the distance modulus of the LMC, both using RR Lyraes and other distance indicators.

Below are some comments on the entries on Table 3.

RR Lyraes. There are observations of RR Lyraes in 5 LMC Clusters (Walker 1992, Reid and Freedman 1994) and combining the data from the clusters gives a mean dereddened magnitude m_v of 18.98 and a mean [Fe/H] of -1.8. From Eq. (1) we obtain a distance modulus (m-M) of 18.26±0.15.

Recently several groups have worked on Baade-Wesselink analyses of RR Lyrae stars (Liu and Janes 1990a, Jones et al. 1992, Cacciari et al. 1992, Skillen et al. 1993 and Fernley 1994) and results of the different groups are reasonably consistent. Taking a simple mean gives

$$M_v = 0.20 \pm 0.04[Fe/H] + 1.03 \pm 0.14 \quad (2)$$

where the error on the zero-point comes from both the random error, ±0.06, and the estimated systematic errors in the Baade-Wesselink method, ±0.12. At [Fe/H]=-1.53 Eq. (2) predicts M_v=0.73±0.14 which is in good agreement with the zero-point derived from the HIPPARCOS data in Eq. (1), which is itself based on two independent methods. In our opinion this agreement in the zero-point between three completely independent methods of analysis is the main result of this paper.

Nonetheless it is clear from Table 3 that the resulting LMC distance moduli from the RR Lyraes are in general lower than those from other distance indicators. Are there other factors which could be affecting the distance estimate ? One possibility is depth effects in the LMC. The observed diameter of the LMC is $7^o.7$ and if the depth is comparable to the width this would be equivalent to ± 0.14 in (m-M). However, this is unlikely to be significant in the present case since the mean m_v for the RR Lyraes is based on observations of RR Lyraes in 5 clusters which are spread evenly across the face of the LMC (Walker 1992).

Another possibility is that, for some reason, RR Lyraes in clusters are not the same as RR Lyraes in the field. Liu and Janes (1990b) did Baade-Wesselink analyses of 4 RR Lyraes in the Globular Cluster M4 ([Fe/H]∼-1.4) and Storm et al. (1994) did Baade-Wesselink analyses of 2 RR Lyraes in M5 ([Fe/H]∼-1.5) and 2 in M92 ([Fe/H]∼-2.1). For the intermediate metallicity clusters M4 and M5 the absolute magnitudes derived by these authors were in the mean 0.03 mags fainter (M4) and 0.06 mags brighter (M5) than predicted by Eq. (2), which is the Baade-Wesselink relation for field stars. For the metal-poor cluster M92 the derived absolute magnitudes were 0.14 mags brighter than predicted by Eq. (2). Because of the difficulty of doing Baade-Wesselink analyses of such relatively faint stars the quoted error on these absolute magnitudes was ±0.20 mags. Certainly for the intermediate metallicity clusters the level of agreement between the field and cluster RR Lyraes is very good. For M92 the agreement is less good and we note here the discussion by Storm et al. concerning the relative fractions of "normal" and "evolved" RR Lyraes in the RR Lyrae Instability Strip as a function of metallicity. In intermediate metallicity clusters it is expected that the majority of RR Lyraes are "normal", i.e. stars on the zero-age Horizontal Branch. In more metal-poor clusters it is expected that there will be an increasing number of "evolved" RR Lyraes, i.e. stars with zero-age Horizontal Branch positions to the blue of the Instability Strip and which are now crossing the Instability Strip during their redward evolution towards the Asymptotic Giant Branch. In general the "evolved" RR Lyraes will be brighter than "normal" RR Lyraes. If this argument is correct then RR Lyraes in more metal-poor clusters will, in the mean, be brighter than predicted by Eqs. (1) and (2). A similar result was obtained by Lee et al. (1990) who constructed synthetic Horizontal Branches from grids of evolutionary tracks. These showed that, for more metal-poor clusters, the mean level of the Horizontal Branch was ∼0.1 brighter than the zero-age level, this being due to the mixing of "normal" and "evolved" RR Lyraes. In the present context, any brightening of the mean level of the Horizontal Branch due to the presence of significant numbers of "evolved" stars, will increase the derived LMC distance.

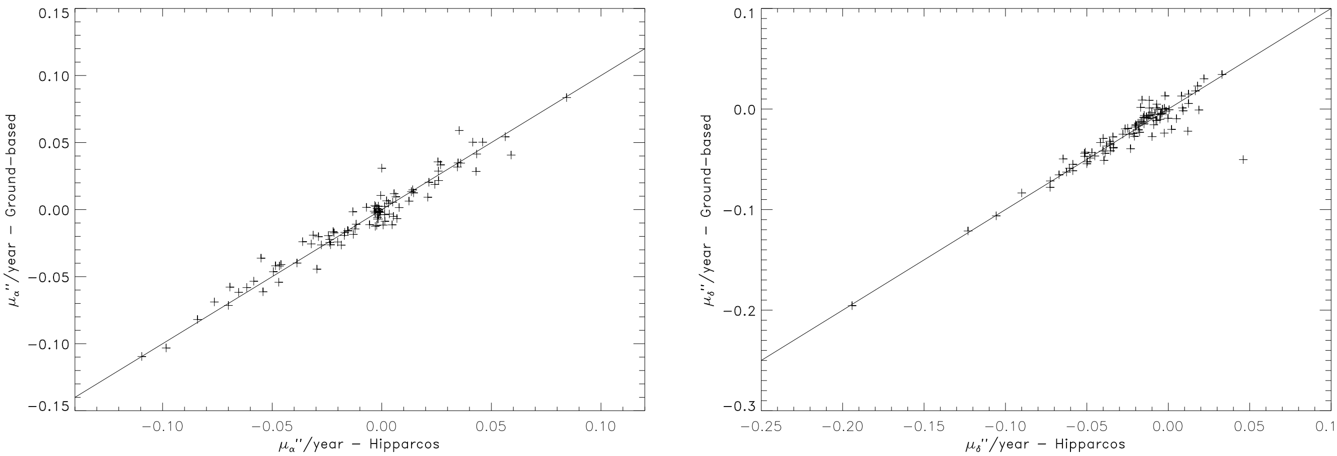

Fig. 1. A comparison between the HIPPARCOS and ground-based proper motions. The solid line has slope unity.

Table 3. LMC distance moduli

Method	(m-M)
RR Lyraes - HIPPARCOS data (this paper)	18.26±0.15
RR Lyraes - Baade-Wesselink (see text)	18.31±0.14
Cepheids - Field Stars HIPPARCOS data (Feast and Catchpole 1997)	18.70±0.10
Cepheids - Cluster stars HIPPARCOS data (see text)	18.33±0.10
Cepheids - Baade-Wesselink (Gieren et al. 1993)	18.65±0.10
Cepheids - Baade-Wesselink (Gieren et al. 1997)	18.49±0.05
Miras - HIPPARCOS data (van Leewuen et al. 1997)	18.54±0.18
SN1987A Ring - Gould and Uza (1997)	18.37±0.04
SN1987A Ring - Sonneborn et al. (1997)	18.43±0.10
SN1987A Ring - Panagia et al. (1997)	18.58±0.03
SN1987A Ring - Lundqvist and Sonneborn (1997)	18.67±0.08

Cepheids. It can be seen from Table 3 that the Cepheids produce a less consistent set of results. This is particularly striking in the applications of HIPPARCOS data. Feast and Catchpole (1997) used HIPPARCOS parallaxes of local field Cepheids to determine the zero-point of the Cepheid Period-Luminosity relation and hence derive an LMC distance modulus of 18.70±0.10. By contrast the Cluster Cepheids give a distance modulus of 18.33±0.10, based on the work of Feast (1995) corrected to the HIPPARCOS Pleiades distance modulus of 5.33±0.06 (Mermilliod et al. 1997). The work of Feast and Catchpole has also been criticised by Szabados (1997), who argues that the large number of binaries amongst the HIPPARCOS Cepheids leads to a systematic under-estimate of parallaxes (and hence too bright a zero-point and too large an LMC distance modulus). It is clear that the results from applying HIPPARCOS data to Cepheids are still in their early stages.

A more consistent set of values for the Cepheids comes from the Baade-Wesselink analyses of Gieren et al. (1993, 1997), the former using purely optical data and the latter using both optical and infrared data.

A simple mean of the 4 Cepheid distance moduli gives a value of 18.54, which is ∼0.25 larger than given by the RR Lyraes. In this matter we note the recent work of Sekiguchi and Fukugita (1997) concerning the sensitivity of the zero-point of the Cepheid P-L relation to metallicity effects. They used the high quality abundances derived for 23 galactic Cepheids by Fry and Carney (1997) to show that the residuals from the Cepheid P-L relation are strongly correlated with metallicity, specifically ΔM_v = -2.15[Fe/H]. Assuming the Cepheids in the LMC are slightly metal-poor compared to Galactic Cepheids, ∼-0.15 dex (Feast and Walker 1985), then the relation found by Sekiguchi and Fukugita would reduce the Cepheid LMC distance modulus by 0.32.

Miras. van Leewuen et al. (1997) have used HIPPARCOS parallaxes of nearby Miras to calibrate the Mira P-L relations. Examination of the resulting plots (their Figs 2 and 3) shows a relatively poor fit, with 4 out of the 8 high-weight stars lying

2 or more sigma from the line. It seems clear that there are systematic effects that have not been completely dealt with in the analysis, possibly metallicity effects in the stars or biases in the parallaxes due to surface inhomogeneities on the stars (note that Miras have angular diameters that are typically an order of magnitude larger than their parallaxes).

SN1987A. Four papers published this year show a range of values between 18.37 and 18.67 for the LMC distance modulus derived from SN1987A. It is clear that the early hopes that SN1987A would give the definitive LMC distance are, as yet, unfulfilled.

5.2. Ages of the Globular Clusters

Chaboyer et al. (1996) discuss the ages of the Globular Clusters using the Yale isochrones and Globular Cluster observations from the literature. They derive ages using several different assumptions about the RR Lyrae M_v, [Fe/H] relation. Interpolating amongst their relations in order to fit our Eq. (1) we obtain a mean age of 17.4±3.0 GYrs.

Reid (1997) has recently claimed a mean age of $\sim$ 12 GYrs. The difference between the two ages is entirely due to the distance calibration. Reid obtains distances to the Globular Clusters by fitting their main sequences to local subdwarfs whose absolute magnitudes he determines from their HIPPARCOS trigonometric parallaxes. This distance scale is $\sim$0.35 mags longer than the RR Lyrae distance scale given by Eq. (1). Two other groups have also analysed the HIPPARCOS trigonometric parallaxes of local subdwarfs. Fusi Pecci et al. (1997) obtain similar results to Reid, however Pont et al. (1997) make the subdwarfs fainter by $\sim$0.30 mags, i.e. consistent with the RR Lyraes. At the present time the situation with the subdwarfs is not clear, in particular the important question of when to apply bias corrections to HIPPARCOS parallaxes is not settled.

6. Summary

Using HIPPARCOS data we obtain the following estimates of the zero-point of the RR Lyrae M_v,[Fe/H] relation, firstly, M_v=0.77±0.17 at [Fe/H]=-1.66 using the Method of Statistical Parallax and HIPPARCOS proper motions for 84 Halo Field RR Lyraes and secondly, M_v=0.78±0.29 at [Fe/H]=-1.39 from the HIPPARCOS trigonometric parallax of the single star RR Lyrae itself. These two estimates are in excellent agreement and give a final value of M_v=0.77±0.15 at [Fe/H]=-1.53. This in turn is in very good agreement with the zero-point derived recently by several groups using Baade-Wesselink methods, namely M_v=0.73±0.14 at [Fe/H]=-1.53. In our opinion this level of agreement, between three completely independent methods, as to the value of the zero-point of the RR Lyrae M_v,[Fe/H] relation is the main result of the paper.

Taking the HIPPARCOS zero-point and a value of 0.18±0.03 for the slope of the relation from the literature we find firstly, the distance modulus of the LMC is 18.26±0.15 and secondly, the mean age of the Globular Clusters is 17.4±3.0 GYrs. Comparing these values with recently published estimates, using other "standard candles" also calibrated with HIPPARCOS data, shows that there remain unresolved problems, both with the astrophysics and with the interpretation of HIPPARCOS data itself.

Interpretation of HIPPARCOS data. Firstly, in what cases should bias corrections be applied to the parallaxes ? This has a significant effect on the calibration of the subdwarfs (used to determine the distance and ages of the Globular Clusters - see Sect. 5.2). Secondly, for stars that are in binaries, what is the effect of the orbit on the observed parallax ? This has implications for the calibration of the zero-point of the Cepheid P-L relation (and hence the distance to the LMC - Sect. 5.1). Thirdly, for stars with very large angular diameters, what is the effect of surface inhomogeneities on the observed parallax ? This has relevance for the Miras (again Sect. 5.1).

Astrophysical problems. Firstly, what is the sensitivity of the zero-point of the Cepheid P-L relation to metallicity ? If, as suggested by recent work, this is significant then the metallicity differences between Cepheids in the Galaxy and the LMC will obviously lead to incorrect distance estimates (see discussion in Sect. 5.1). Secondly, what is the effect of evolution on the mean magnitude of RR Lyrae stars in metal-poor clusters ? If this effect is significant then the RR Lyraes in these clusters will be brighter than predicted, and hence the LMC distance would be increased and the Globular Cluster ages would be reduced (again see discussion in Sect. 5.1).

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References

Breger M., 1964, MNASSA 23, 112
Burstein D., Heiles C., 1982, AJ 87, 1165
Butler D., 1975, ApJ 200, 68
Cacciari C., Clementini G., Fernley J., 1992, ApJ 396, 219
Cacciari C., Clementini G., Lindgren H., 1990, A&AS 85, 865
Cacciari C., Clementini G., Prevot L., Lindgren H., Lolli M., Oculi L., 1987, A&AS 69, 135
Carrillo D., Burki G., Mayor M., Burnet M., Lampens P., Nicolet B., 1995, A&AS 113, 483
Chaboyer B., Demarque P., Sarajedini A., 1996, ApJ 459, 558
Clementini G., Carretta E., Gratton R., Merighi R., Mould J.R., McCarthy J.K., 1995, AJ 110, 2319
Clementini G., Tosi M., Merighi R., 1991, AJ 101, 2168
Clube V., Evans D., Jones D., 1969, Mem.RAS 72, 101
Feast M.W., 1995, in: Astrophysical Applications of Stellar Pulsation, eds. R. Stobie and P. Whitelock, ASP Conf. Series 83, 209
Feast M.W., 1997, MNRAS 284, 761
Feast M.W., Catchpole R.M., 1997, MNRAS 286, L1
Feast M., Walker A., 1985, ARA&A 25, 345
Fernley J., 1993a, A&A 268, 591
Fernley J., 1993b, Observatory 113, 197
Fernley J., 1994, A&A 284, L16
Fernley J., Barnes T.G., 1997, A&AS In Press
Fernley J., Carney B., Skillen I., Cacciari C., Janes K., 1997, MNRAS Submitted
Fernley J., Skillen I., Burki G., 1993, A&AS 97, 815

Fernley J., Skillen I., Jameson R.F., Barnes T.G., Kilkenny D, Hill G., 1990, MNRAS 247, 287
Fry A.M., Carney B.W., 1997, AJ 113, 1073
Freedman W.L., Madore B.F., Kennicutt R.C., 1997, in: The Extragalactic Distance Scale, Eds. M. Donahue, M. Livio, Cambridge University Press.
Fusi Pecci F., Clementini G., Carretta E., Gratton R.G., Lattanzi M.G., Corsi C.E., 1997, in: HIPPARCOS Venice'97, ESA-SP 402
Gieren W.P., Barnes T.G., Moffett T.J., 1993, ApJ 418, 135
Gieren W.P., Fouque P., Gomez M., 1997, in: A half-century of Stellar Pulsation interpretations: A tribute to Arthur N. Cox, eds J. Guzik and P. Bradley, ASP Conf. Series, In Press
Gould A., Uza O., 1997, ApJ, In Press
Hanson R.B., 1979, MNRAS 186, 875
Hawley S.L., Barnes T.G., 1985, PASP 97, 551
Hawley S.L., Jefferys W.H., Barnes T.G., Wan L., 1986, ApJ 302, 626
Jones R., Carney B., Latham D., 1988, ApJ 332, 206
Jones R., Carney B., Storm J., Latham D., 1992, ApJ 386, 646
Joy A.H., 1938, PASP 50, 302
Joy A.H., 1950, PASP 62, 60
Joy A.H., 1955, PASP 67, 420
Kemper E., 1982, AJ 87, 1395
Kholopov P.N., et al, 1985, in: General Catalogue of Variable Stars (GCVS), Nauka Publishing House
Kinman T.D., 1961, Royal Obs. Bull. 37, 151
Kinman T.D., Carretta E., 1992, PASP 104, 111
Klemola A.R., Jones B.F., Hanson R.B., 1987, AJ 94, 501
Lambert D.L., Heath J.E., Lemke M., Drake J., 1996, ApJS 103, 183
Layden A.C., 1994, AJ 108, 1016
Layden A.C., Hanson R.B., Hawley S.L., Klemola A.R., Hanley C.J., 1996, AJ 112, 2110
Lee Y.W., Demarque P., Zinn R., 1990, ApJ 350, 155
Liu T., Janes K.A., 1990a, ApJ 354, 273
Liu T., Janes K.A., 1990b, ApJ 360, 561
Lundqvist P., Sonneborn G., 1997, in: SN1987A: Ten Years After, eds M. Phillips and N. Suntzeff, ASP Conf. Series, In Press
Lutz T.E., Kelker D.H., 1973, PASP 85, 573
Mermilliod J.C., Turon C., Robichon N., Arenou F., 1997, in: HIPPARCOS Venice'97, ESA-SP 402
Meylan G., Burki G., Rufener F., Mayor M., Burnet M., Ischi E., 1986, A&AS 64, 25
Notni P., 1956, Mitt.Jena 26
Panagia N., Gilmozzi R., Kirshner R., 1997, in: SN1987A: Ten Years After, eds. M.Phillips and N.Suntzeff, ASP Conf. Series, In Press
Pont F., Mayor M., Turon C., Lebreton Y., Charbonnel C., 1997, in: HIPPARCOS Venice'97, ESA-SP 402
Preston G.W., 1959, ApJ 130, 507
Reid I.N., 1997, AJ In Press
Reid I.N., Freedman W., 1994, MNRAS 267, 821
Saha A., White R.E., 1990, PASP 102, 148
Schmidt E.G., 1991, AJ 102, 1766
Schmidt E.G., Chab J.R., Reiswig D.E., 1995, AJ 109, 1239
Sekiguchi M., Fukugita M., 1997, Preprint
Simon N., Teays T., 1982, ApJ 261, 586
Skillen I., 1985, Ph.D. Thesis, Univ. of St. Andrews, Scotland
Skillen I., Fernley J., Stobie R.S., Jameson R.F., 1993, MNRAS 265, 301
Smith H., 1990, PASP 102, 124
Solano E., Garrido R., Fernley J., Barnes T.G., 1997, A&AS In Press
Sonneborn G., Fransson C., Lundqvist P., Cassatella A., Gilmozzi R., Kirshner R., Panagia N., Wamsteler W., 1997, ApJ 477, 848
Storm J., Carney B.W., Latham D.W., 1994, A&A 290, 443
Strugnell P., Reid I.N., Murray C.A., 1986, MNRAS 220, 413
Suntzeff N.B., Kinman T.D., Kraft R.P., 1991, ApJ 367, 528
Szabados L., 1997, in: HIPPARCOS Venice'97, ESA-SP 402
van Leeuwen F., Evans D.W., 1997, A&A Submitted
van Leewuen F., Feast M., Whitelock P., Yudin B., 1997, MNRAS 287, 955
Walker A.R., 1992, in: New Results on Standard Candles, Ed. F. Caputo, Mem. Soc. Ast. Italiana 63, 479
Woolley R., Ali K., 1966, Royal Obs. Bull. 114

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