COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS

Number 5354

Konkoly Observatory
Budapest
17 December 2002

HU ISSN 0374 – 0676

THE ABSOLUTE MAGNITUDE (M_V) OF TYPE *AB* RR LYRAE STARS

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RR Lyrae stars are commonly used as tracers of the halo population in both galactic and extragalactic work. Such studies require a knowledge of their absolute magnitude M_v. If their metallicity is known, it has been customary to use an empirical linear relation in terms of [Fe/H]:

$$M_v = A[Fe/H] + B \tag{1}$$

Chaboyer (1999) gives 0.23 and 0.93 while Cacciari (2002) gives 0.23 and 0.92 for the coefficients A and B, respectively. These values are consistent with the widely-used LMC modulus of 18.50±0.10 (Freedman *et al.*, 2001), van der Marel *et al.* (2002)). If we assume a mean RR Lyrae metallicity of −1.6, these relations give an $\langle M_v \rangle$ of +0.55 or +0.56 with an uncertainty of about ±0.10 mag.; this is in the middle of the range of recent direct determinations of the M_v of type *ab* RR Lyrae stars (Popowski & Gould, 1999).

Kovács & Walker (2001) have given an empirical expression for M_v in terms of the period (P) and Fourier coefficients (A1 and A3) of the variables:

$$M_v = -1.876 \log P - 1.158 A1 + 0.821 A3 + K \tag{2}$$

Here K is a constant which must be determined. Benedict *et al.* (2002) derived an M_v of +0.61±0.10 for RR Lyrae itself from a parallax derived from HST data; this corresponds to a modulus (corrected for extinction) of 7.06. RR Lyrae shows a 41-day modulation of its amplitude (Blazhko effect) and the amplitude of this modulation also varies over a 4-year period (Detre & Szeidl, 1973). Jurcsik *et al.* (2002) have examined the Fourier coefficients of RR Lyrae and shown that they only correspond to those of a normal type *ab* star when both RR Lyrae has the maximum amplitude of its 41-day cycle and when the amplitude of the 4-year cycle is at a minimum. Observations that fulfil this condition were made by Hardie (1955) in the interval JD 2 434 553 to JD 2 434 560. The corresponding cycles in Hardie's data are 34749 to 34761 (using Walraven's period of 0.56683735 days). The Fourier coefficients A1 and A3 derived from this portion of Hardie's data are 0.31539 and 0.09768, respectively. Using these in eqn. (2), one finds K = 0.43.

One can check this result by comparing the absolute magnitudes derived by eqn. (2) against those obtained from eqn. (1) using a group of nearby RR Lyrae stars that have both well-determined Fourier coefficients and also known metallicities. There are 73 type *ab* stars whose Fourier coefficients are given by Jurcsik & Kovács (1996) that also have

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[Fe/H] given by Layden *et al.* (1996). For these one can calculate both M_v(Four) from eqn. 2 with K = 0.43, and also M_v(Fe) from eqn. (1) using Cacciari's coefficients. The differences (Δ M_v = M_v(Four) $-$ M_v(Fe)), are plotted in Fig. 1 against (a) log P and (b) metallicity [Fe/H]. Eight of these variables (shown by crosses in Fig. 1) have peculiar relations between their Fourier components according to Jurcsik & Kovács (1996); two of these AN Ser (P = $0\overset{d}{.}52$ days, [Fe/H] = -0.04) and TV Lib (P = $0\overset{d}{.}27$ days, [Fe/H] = -0.27) clearly show abnormally large ΔM_v in Fig. 1. The scatter in ΔM_v is larger for stars of longer period and lower metallicity. This is understandable since the longer period stars have lower amplitudes and so their Fourier coefficients will be less well determined for a given photometric accuracy. Similarly, the metallicities will be more poorly determined in the lower metallicity stars whose lines are weaker. Additionally, there may be physical differences between the Oosterhoff I and II populations that contribute to this increased dispersion. Omitting the eight stars that have peculiar relations between their Fourier coefficients, the remaining 65 stars have a mean value of ΔM_v of $+0.010\pm0.008$ with an *rms* deviation for a single star of 0.063 mag. If one includes all these stars except AN Ser and TV Lib, the mean value of ΔM_v is $+0.007\pm$ 0.008 with an *rms* deviation for a single star of 0.066 mag. Thus the two ways of estimating M_v for type *ab* RR Lyrae stars give very similar results in this sample of 71 stars.

There will be cases where neither [Fe/H] is known nor is it possible to get the Fourier components from the light curves with sufficient accuracy. One cannot simply replace the expression containing the Fourier coefficients (in eqn. 2) with a constant because this expression shows some correlation with log P. An adjustment must be made to the coefficient of log P to allow for this; one then gets:

$$M_v = -1.619 \log P + 0.20 \tag{3}$$

Calling this absolute magnitude M_v(Per), the differences δM_v = M_v(Per) $-$ M_v(Fe) were calculated and are plotted in Fig. 2 against (a) log P and (b) [Fe/H] for *all* 73 stars in the Jurcsik & Kovács sample. None of the eight stars that have peculiar Fourier coefficients (shown in Fig. 2 by crosses) are anomalous in this plot. For all 73 stars the mean value of δM_v is -0.003 ± 0.006 mag. with an *rms* deviation for a single star of 0.048 mag. For this sample of stars therefore, eqn. (3) is at least as good an estimator of M_v as eqn (2), although there appears to be a slight trend of δM_v with [Fe/H].

A semi-empirical relation for M_v in terms of log P and the blue amplitude of the variable (A_B) has been given by Castellani & De Santis (1994) and was further discussed by De Santis & Cassisi (2002). Now A_B correlates with log P, and so eqn. (3) can also be regarded as a simplified version of such relations

The three empirical relations given by equations (1), (2) and (3) allow alternative ways of finding M_v for a sample of RR Lyrae stars that may be used (and compared) depending on the observational data that is available. They are generally consistent with a widely used modulus (18.50) for the LMC.

Acknowledgements: I would like to thank Dr Carla Cacciari for helpful comments on this work and also Dr Christine Clement for the use of her program for the Fourier analysis of the light-curves.

†For early discussions of such relations see Sandage (1958) and Kinman (1959)..

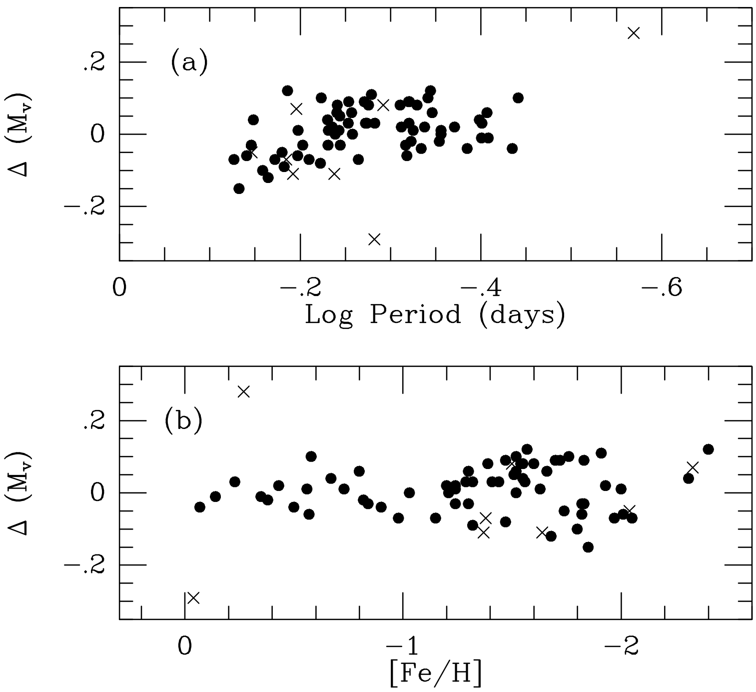

Figure 1. The magnitude difference ΔM_v as a function (a) of $\log P$ and (b) [Fe/H]

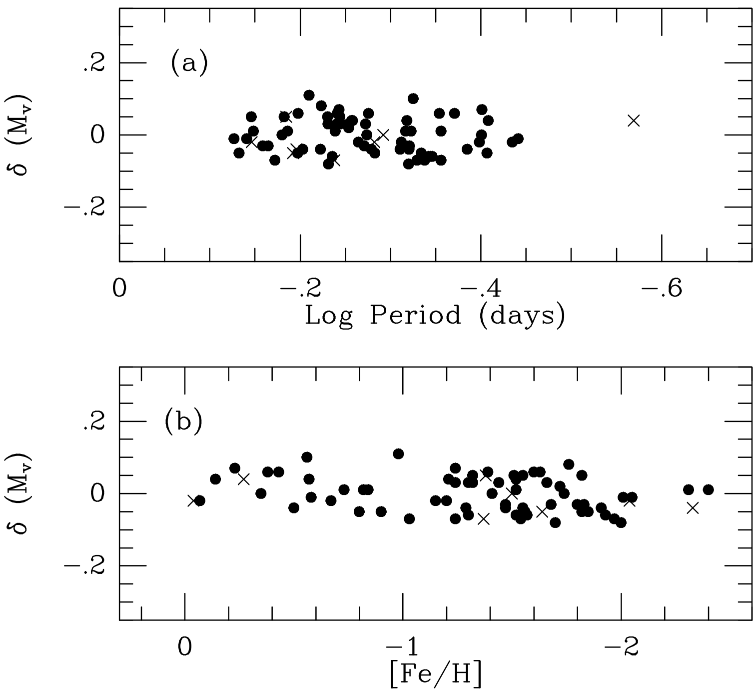

Figure 2. The magnitude difference δM_v as a function (a) of $\log P$ and (b) [Fe/H]

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