RR LYRAE VARIABLE STARS AND THE DISTANCE SCALE

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A statistical parallax algorithm (Clube and Dawe, 1978a,b), using the technique of maximum likelihood, has been applied to a set of 103 'ab' - RR Lyrae stars in the solar neighborhood (r 2<kpc), using observational data from the Royal Greenwich Observatory Bulletins. A second set of 130 'ab' - RR Lyrae stars has been kindly supplied to us by Dr. A. Heck (Université de Liège) to permit a comparison between our analyses. The purpose of this investigation was:

(a) to investigate the variations of kinematical parameters and absolute luminosities of these stars as functions of Preston's index ΔS and of log (Period).

(b) to identify those RR Lyrae stars in the solar neighborhood which most closely resemble those in the galactic halo, those near the galactic center, and those in the Magellanic Clouds.

To perform this analysis, the stars were divided into limited ranges of ΔS and log (Period), but with the constraint that each range should contain at least 30 members. (The minimum population required to give statistically useful solutions. Because of this constraint, adjacent bins often conain several members in common.) The results are summarized in Fig. 1.

A. G. Davis Philip and D. S. Hayes (eds.), The HR Diagram, 53-57.

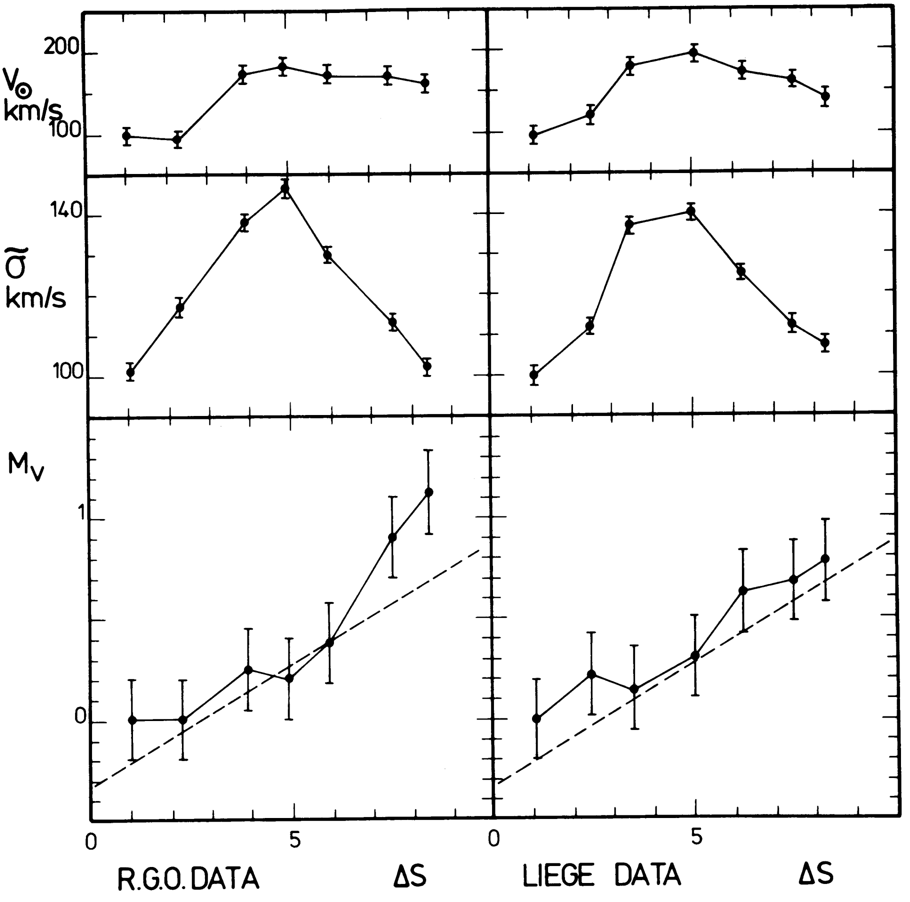

Fig. 1. The variations of solar reflex motion, $V_\odot$, mean velocity dispersion, $\tilde{\sigma}$, and absolute visual magnitude, M_V, as functions of Preston's index, ΔS, for local 'ab'- RR Lyrae stars.

https://doi.org/10.1017/S0074180900145255 Published online by Cambridge University Press

V_{Θ} is the scalar value of the solar reflex vector, $\tilde{\sigma}$ is the mean velocity dispersion ($= \{[\sigma_u^2 + \sigma_v^2 + \sigma_w^2]/3\}^{\frac{1}{2}}$) and M_V is the visual absolute magnitude, corrected for absorption. In the case of the R.G.O. data, Bernicki's empirical reddening law (Bernicki, 1967) has been applied to the observed color of each star, while for the Liege data a Parenago-type global formula has been used (Sharov, 1964). Both sets of data indicate the same general behavior namely, a gradual increase in the solar velocity with increasing ΔS, and a sharp maximum in the velocity dispersion at intermediate values of ΔS. There is a significant correlation between the absolute magnitude and ΔS, which is steeper in the case of the R.G.O. data. The dotted line in Fig. 1 shows the linear correlation found by Dr. Heck from his own data (Heck, private communication). The differences between our two results may arise from:

(1) differences in absorption corrections: There are indications that Bernicki's rule might overestimate the absorption by $\Delta A_v \sim 0\overset{m}{.}1$ (e.g. see Bernicki, 1967). However, we have chosen not to correct for this, as its effect may be counterbalanced by a correction necessary to the systematic motion of the reference stars. This amounts to $\Delta\mu = -0.007$ arcseconds p.a. in the direction of galactic rotation and appears to be confirmed by the work of Klemola and Vasilevskis (1971). When applied, such a correction would systematically make the absolute magnitude $0\overset{m}{.}1$ fainter for <u>both</u> sets of data.

(2) differences in the maximum-likelihood algorithms used: Both algorithms have been checked with a single set of synthetic RR Lyrae data, supplied by Dr. D. Jones of R.G.O., and their solutions in this case differ by no more than $\Delta M_v = M_v$ (Heck) $-M_v(\mathrm{CD}) = -0\overset{m}{.}06$ ($\Delta V = -4\mathrm{kms}^{-1}$, $\Delta\sigma = 1\mathrm{kms}^{-1}$).

(3) differences in stellar data: The R.G.O. data set was selected so that both proper motions and radial velocities are on uniform systems. No stars of period greater than $0\overset{d}{.}8$ are included, while Heck's set contains 2 stars with periods greater than $1\overset{d}{.}2$.

A simple interpretation of these results is that we are dealing with a mixture of at least two populations: a low-velocity component with $V \sim 50\mathrm{kms}^{-1}$, corresponding to $\Delta S \leqslant 1$, and a high velocity component with $V \sim 180\mathrm{kms}^{-1}$, corresponding to $\Delta S \geqslant 7$. The mean velocity variance of each population would appear to be $\sim 100\ \mathrm{kms}^{-1}$, the sharp peak which is manifest at $\Delta S \sim 5$ arising from the mixing of two Gaussian populations with different mean velocities.

The correlation between M_v and log (Period) is much less clear, as the periods are correlated with ΔS. Superficially, the solar reflex motion and the velocity dispersion appear to behave with increasing period in much the same manner as they do with increasing ΔS.

Of the RR Lyrae stars investigated, we identify those with $\Delta S \geqslant 6$ as being a representative sample of the high-velocity population (though with some contamination at the 10% level). The m.l. solution for this set of stars is given in Table I.

TABLE I: M.L. SOLUTION FOR HIGH-ΔS RR LYRAE STARS

$$N = 54 \quad ; \quad \overline{\Delta S} = 7.6$$

$$M_V = 1^m\!.0 (\pm 0^m\!.2) \quad ; \quad \sigma(M_V) = 0^m\!.6 \ (\pm 0^m\!.3)$$

$$U = -2 \ , \quad V = -165 \ , \quad W = -18 \ ; \quad V_\odot = 166 \quad \text{kms}^{-1}$$

$$\sigma_u = 145 \ , \quad \sigma_v = 100 \ , \sigma_w = 72 \quad ; \quad \tilde{\sigma} = 110 \quad \text{kms}^{-1}$$

If this high-velocity sample is similar to the RR Lyrae population at the galactic center, the galactic halo and the Magellanic Clouds, and there is evidence from their respective period-frequency distributions that this is likely to be the case for at least the latter two, then the derived absolute magnitude may be used to re-calibrate the distance scale to the galactic center and to the Clouds. Using the work of Oort and Plaut (1975), and Graham (1974, 1975), we find:

$$R_o = 7.1 \ (\pm 0.7) \ \text{kpc}$$

$$\left.\begin{array}{l} \mu(\text{SMC}) = 18^m\!.6 \\ \mu(\text{LMC}) = 18^m\!.2 \end{array}\right\} \ \underline{\text{uncorrected}} \text{ for interstellar absorption.}$$

If $A_V(\text{SMC}) = 0^m\!.3$ for both the SMC and LMC, then:

$$r \ (\text{SMC}) = 46 \ \text{kpc.}$$

$$r \ (\text{LMC}) = 38 \ \text{kpc.}$$

REFERENCES

Clube, S.V.M. and Dawe, J.A. (1978a,b). submitted to Monthly Notices Roy. Astron. Soc.
Bernicki, A. (1967). Acta Astron. **17**, 165.
Graham, J.A. (1974). In IAU Symposium No. 50, Stellar Instability and Evolution, P. Ledoux, A. Noels and A.W. Rodgers, eds., D. Reidel, Dordrecht, p. 107
Klemola A.R. and Vasilevskis, S. (1971). Publ. Lick. Obs. XXII, Part III.
Oort, J.H. and Plaut, L. (1975). Astron. Astrophys. **41**, 71.
Sharov, A.S. (1964). Soviet Astron. **7**, 689.

https://doi.org/10.1017/S0074180900145255 Published online by Cambridge University Press

DISCUSSION (The paper was read by Dickens)

COX: Can you tell us the numerical value of the color term in the P-L-C relation? There is theoretical evidence that the value of d log L/d log T_{eff} for constant period in the HR diagram is five rather than six from Sandage and Tammann Cepheid data.

DICKENS REFERS TO MADORE

MADORE: The resulting change in the color term in the P-L-C relation suggested by Clube's revision is quite large. From the value of 2.5, suggested by Sandage and Tammann for the (B-V) color term, Clube requires a slope closer to unity or even less.

KRAFT: Can you explain why the present result on the dependence of M_V on ΔS reverses the result found from RGO work of 10 years ago?

DICKENS: I am not familiar with the details of all this. However I suspect that a) the data sample has enlarged considerably, b) the methods of analysis are different and c) changes may have occurred in the adopted constants of the proper motion reference frame.

KRAFT: One notes that the results obtained from RR Lyraes in ω Cen show that there is no dependence of M_V on ΔS.

DICKENS: The RR Lyraes in ω Cen may well have a different chemical evolutionary history from those in the Galaxy. For example, a relatively small change in helium abundance can have a substantial effect on the luminosity at which stars of a given mass pass through the instability strip.

KRAFT: M_V increases with ΔS in Clube's work. But from stellar evolutionary theory and from Wesselink's method, one gets M_V more or less constant with ΔS, or at least a much smaller dependence.

DICKENS: It should be emphasized that only for the high ΔS group (>7) do we have a "pure" population sample. For intermediate and small values of ΔS, the statistical parallax results for M_V probably represent mixed populations and therefore any apparent correlation of M_V with ΔS must be treated with caution.

BIDELMAN: What is ΔS thought to be for the RR Lyraes in the galactic center? Is it in fact 7.5 or so?

KRAFT: I believe the few that have been done directly have a mean in the region of ΔS=3, but it must be remembered that the galactic center region contains a mixture of population types ranging from ΔS=0 to 8.

DICKENS: This means that the results for the high ΔS group (M_V = +1) are not strictly applicable to the galactic center variables.

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