A NON-EXPLANATION OF THE SANDAGE EFFECT: [CNO/Fe] $\neq$ 0

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ABSTRACT

In the log T_e, log P' plot for RR Lyrae variables Sandage (1981) has noted that at a given color the period of the variables decreases as cluster metalicity increases. In particular the variables in M3 were shifted in log P' by 0.065 days compared to M15. The only explanation he could find for this shift was that Y in M3 was 0.05 less than in M15 and thus anticorrelated with Z. I have investigated the possibility that the shift is due to variations in [CNO/Fe]. At least for the range of [CNO/Fe] considered, it does not seem possible to explain the shift at constant Y.

Synthetic horizontal branches have been constructed following the techniques of Rood (1973) and Rood and Seitzer (1980). New ZAHB's with core masses as indicated by red giant calculations have been constructed as necessary. Evolution is only crudely approximated. For M15 the mean mass loss was adjusted so that 70% of the HB was blueward of the variables. For M3 it was adjusted so the number of blue HB was approximately the same as the number of RR Lyrae. Different assumptions have been made concerning the composition and are designated (assuming $Z_\odot = 0.02$):

Name	Y	[Fe/H]	[CNO/Fe]	$\langle \Delta M \rangle$	log $(P')_{3.84}$
M15F	0.75	-2.0	0.0	0.100	-0.304
M15G	0.75	-2.0	0.48	0.147	-0.312
M3F	0.75	-1.6	0.0	0.135	-0.328
M3G	0.75	-1.6	0.25	0.160	-0.322
M3G80	0.80	-1.6	0.0	0.210	-0.378

Figure 1 shows the sort of color-magnitude diagram these simulations produce. ("Observational error" of 0.01 m in V and 0.02 m in B-V is included). Figure 2 shows the log (T_e),

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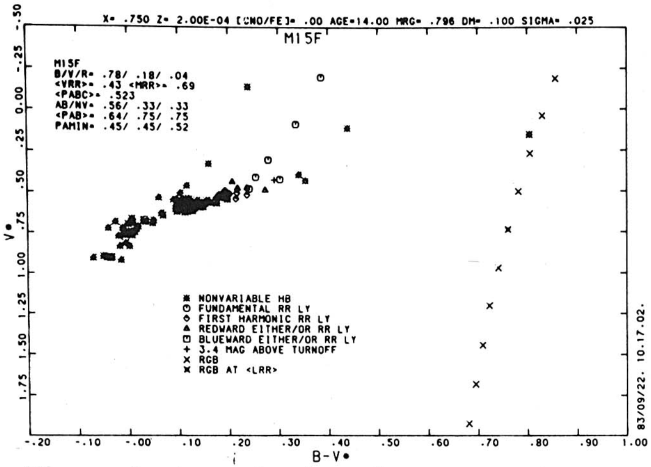

Figure 1. A synthetic color-magnitude diagram for M15.

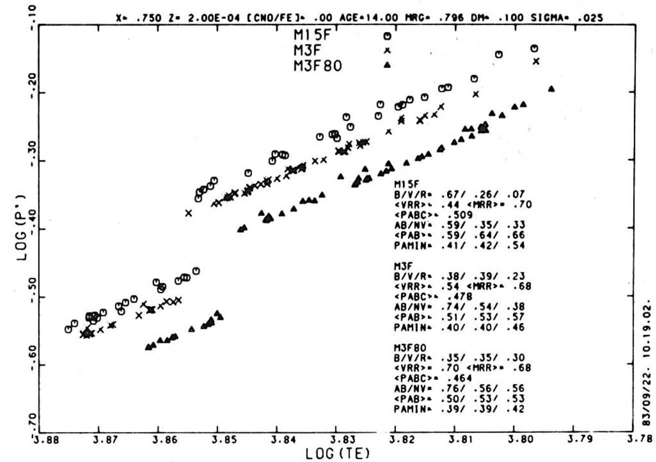

Figure 2. The log of period adjusted for magnitude differences vs. log T_e for [CNO/Fe]=0.

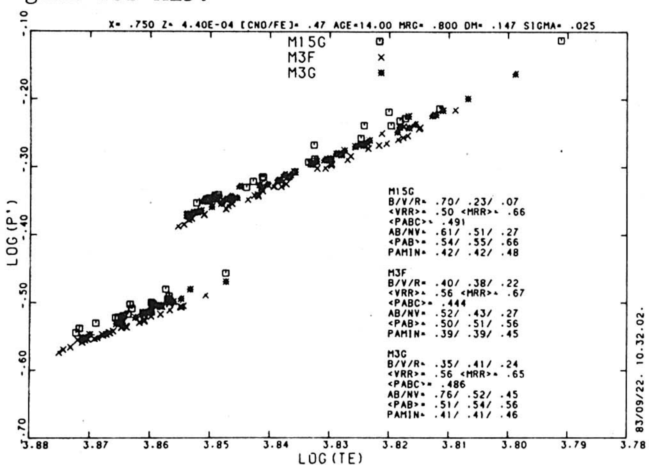

Figure 3. Increasing [CNO/Fe] produces less shift between M15 and M3 than the standard case. See the table for abundances.

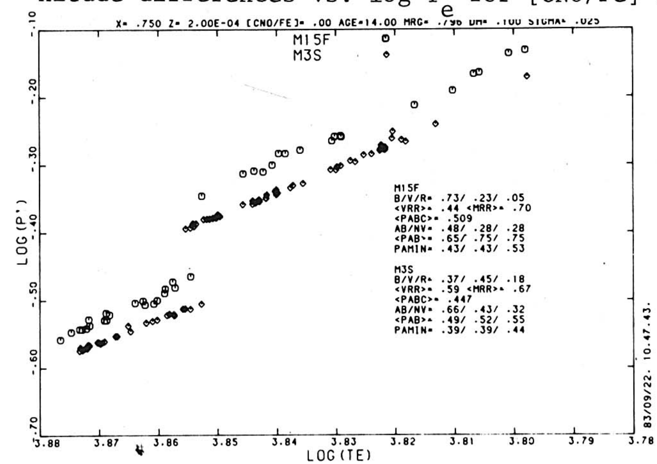

Figure 4. Doubling the Z sensitivity of M_c produces a larger shift but still less than observed.

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log P' [= log (P) + 0.328 ($V-V_{AV}$)] diagram for the standard assumption [CNO/Fe] = 0. The shift at constant Y (log P' at log T_e = 3.84 is given in the table) is about a factor of 3 too small, and Y(M15) = Y (M3) + 0.05 produces the observed shift. Figure 3 shows experiments with increased CNO. Both a CNO enhanced M15 vs. an unenhanced M3, or vs. a slightly enhanced M3 (equivalent to CNO = CNO_o + cons. x Fe) produce even less shift than the standard case. These are small increases in CNO compared to those suggested by Renzini at this meeting, and there may be some threshold effect yet to be exposed. Finally Figure 4 shows the effect of doubling the predicted Z dependence of M core; the observed shift will only be achieved if d M core/d log Z is 5 times the predicted value. At this point it does not appear that a minor shift in the input physics will work.

The same basic conclusions hold for a wider range of [Fe/H] for M3 and M15 than those reported here. The only explanation which I have found is the helium shift. Yet, the helium shift explanation has some difficulties beyond its implausibility. It predicts that the blue edge of the instability strips should shift by $\Delta \log T_e \sim -0.01$ in M3 compared to M15. This corresponds to a shift of roughly 0.03 m in B-V which does not seem out of the question given the errors in reddening. The difficulty arises when the theoretical diagrams are adjusted assuming reddening errors lend to coincident blue edges, the shift in log P' between M3F80 and M15F is then only slightly larger than the standard case, and we are left with no explanation. Further the lower Y for M3 would imply that the gap between turnoff and HB would be 3.25 m rather than the observed 3.4 if M3 is the same age as M15. Neither shifts in Y or CNO produce the mass difference of $-0.1M_\odot$ between M15 and M3 suggested by Cox at this meeting. There is really no satisfactory explanation of the period shift.

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DISCUSSION

Nissen: I would like to ask Renzini about the effect of varying [CNO/Fe]; he seems to reach quite different conclusions.

Renzini: Bob and I have discussed this point at length over the past couple of days. I think we agree that more model calculations are required before concluding about [CNO/Fe] as the cause of the period-shift effect. The reason is that Bob has not computed HB models for [Fe/H] $\simeq$ -1.3 and [CNO/Fe] $\simeq$ 0.5-1.0. Opacities are rather non-linear with abundance of heavy elements, in the interesting temperature range. This may explain Bob's negative result. Also, the opacity tables used by Bob assume [Ne/Fe] = 0 while I would rather expect Ne to follow oxygen rather than iron (on nucleosynthetic arguments). Remember that Ne is at least as important as oxygen, as far as the opacity is concerned.

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