# THE INTERSTELLAR REDDENING AND METALLICITY OF NGC 330

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ABSTRACT. A reddening of E(B-V) = 0.12 ± 0.02 has been determined for NGC 330 in the Small Magellanic Cloud (SMC) from spectrophotometry of B stars in the cluster. This high reddening helps explain many of the anomalous low metallicity estimates for the cluster. Preliminary analysis of Coudé spectra of K giants in the cluster indicates a high value of 3.5 to 4.5 km $s^{-1}$ for the micro-turbulence, and a metallicity near -0.7 dex with respect to the sun..

NGC 330 is the brightest cluster in the SMC. It lies near the centre of the HI distribution in the SMC, along the spine of the stellar distribution, to the NE of the bar and SW of the young stellar groupings of NGC 346 and NGC 371. Colour-magnitude diagrams by Arp (1959) and Robertson (1974) showed bright blue and red supergiants with some extremely bright stars of intermediate colour; Robertson (1973) suggested the main sequence turn-off to be at 13-15 $M_o$ (about $1.2x10^7$ yrs). Carney *et al.* (1985), in an important paper, consider the membership, spectra, photometry and reddening of individual cluster members and discuss the CM diagram and metallicity. They conclude that the reddening is small, E(B-V) = 0.03 ± 0.02, and that the metallicity from several photometric and spectroscopic criteria is very low, probably much less than 1/10 solar, but they caution that the metallicity measures cannot be well quantified because of calibration difficulties. McGregor and Hyland (1984) made photometric observations of CO bands in the red supergiants in NGC 330 and, on the basis of their extreme weakness, suggested a CO deficiency of at least 1/50 solar. Finally, Spite *et al.* (1986) analysed CASPEC spectra of the brightest red supergiant in the cluster, star A7, and derived an average metallicity of around 1/25 solar. All these data showed that the metallicity of NGC 330 was significantly lower than the -0.65 dex (1/4.5 solar) found for the young field population F and G giants in the SMC (Russell *et al.* 1988, Russell and Bessell 1989, Spite *et al.* 1989). How, then, could a young cluster form with a metallicity lower than that of the surrounding field?

Coudé échelle spectra with the 3.9m Anglo-Australian Telescope (AAT) have been obtained for some B giants and red supergiants in NGC 330, and to estimate effective termperatures for these stars, CCD spectrophotometry was made with the Siding Spring Observatory (SSO) 1m telescope. Blue slitless spectra covering the range 310 - 653 nm in one exposure were obtained and reduced to an absolute flux scale using brightness standards of Taylor (1984). Spectra were also obtained for galactic B supergiants in Canis Majoris and Orion. Spectra of individual stars and some representative sky rows from uncrowded regions were extracted from the CCD frames. The raw spectra were divided by the normalised smoothed spectrum of a continuous star to remove the gross curvature of the spectra. This permits more accurate absolute flux calibration to be done using the discrete Taylor 50Å bands which avoid the region of the Balmer Jump. Figure 1 shows



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spectra of NGC 330 stars (identifications Robertson 1974) and the galactic comparison giant stars. The intensity scale is logarithmic. The Balmer jump and the Balmer lines are clearly seen. The spectra have been corrected for reddening (see below).

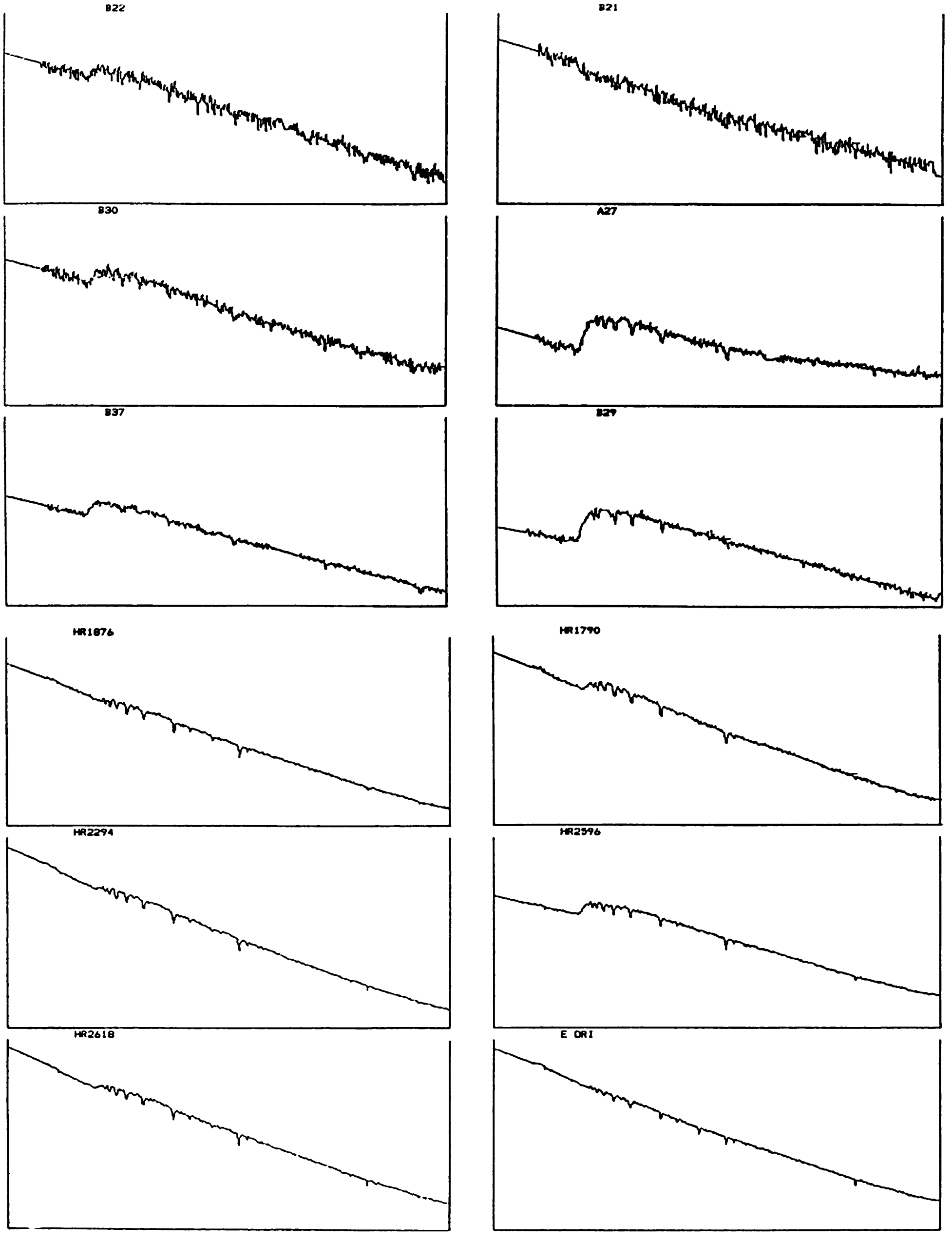


**Figure 1.** CCD spectra of B giants in NGC 330 and the Galaxy from 302 - 653 nm.

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These spectra were used in two ways. Firstly, they were convolved with the standard photometric system passbands to generate synthetic UBV colours, and, secondly, they were dereddened for several different colour excess values using standard reddening laws, then the resultant spectra were fitted by model atmosphere fluxes. All of the comparison stars and the Taylor standards had known UBV colours and so the synthetic UBV photometry was compared with standard UBV values in order to transform the "observed" colours onto the standard system. This required only very small corrections to be made. Table 1 lists the standard synthetic colours corrected for the reddening indicated using the Q-method, and values of the gravity deduced from H and He line fits. As can be seen, the stars encompass similar effective gravities.

**Table 1**

| Star | Sp | $(U-B)_0$ | $(B-V)_0$ | E(B-V) | log g |
|---|---|---|---|---|---|
| HR 1876 | B0.5III | -1.06 | -0.28 | 0.12 | 3.7 |
| HR 2294 | B1II-III | -1.01 | -0.26 | 0.04 | 3.5 |
| HR 2618 | B2II | -0.97 | -0.25 | 0.05 | 3.1 |
| HR 1790 | B2II | -0.91 | -0.26 | 0.05 | 3.3 |
| HR 2596 | B3II | -0.81 | -0.22 | 0.15 | 2.6 |
| NGC 330 | | | | | |
| B22 | | -0.74 | -0.20 | 0.13 | 3.2 |
| B30 | | -0.75 | -0.22 | 0.12 | 3.1 |
| B37 | | -0.75 | -0.20 | 0.10 | 2.8 |
| NGC 1818 D12 | | -0.75 | -0.20 | 0.11 | 2.9 |
| NGC 2004 B15 | | -0.86 | -0.23 | 0.09 | 3.0 |

The reddening values deduced for the galactic giants and the LMC cluster giants appear reasonable; however, the NGC 330 values are much larger than those hitherto accepted for the SMC. In support of this high reddening, Barlow (1990), from a comparison of IUE and optical fluxes, derived E(B-V) ~ 0.12 for the planetary nebula SMC Ln 305, which is within 1 arcmin of NGC 330. In a relevant study, Schwering (1988) derived a very high value of E(B-V) = 0.08 for the galactic foreground reddening of the SMC. It is also of interest that Wolf (1989 private communication) obtained a good fit between theoretical fluxes and the IUE spectra and optical spectra of NGC 330 B30 with extinction values of E(B-V) = 0.08 (galactic) plus 0.04 (SMC), although a lower proportion of foreground extinction was not ruled out.

AAT Coudé échelle red CCD spectra of two red supergiants A7 and B40 in NGC 330 were obtained together with spectra of Arcturus, HH2027 in 47 Tuc, and two galactic K giants HR 263 and HR 2993. From a comparison of R-I, V-K and J-K colours, the galactic and SMC stars could be well ranked in temperature, but comparison of spectral lines of different excitation levels indicated that the SMC stars, although redder than Arcturus, had similar excitation temperatures; the same effect occurred for the red supergiants that were also observed in LMC clusters. We have run preliminary fine analyses for these stars using lines of FeI, TiI and VI only, and have had several interesting results. The spectral lines of the Cloud supergiants look much broader than lines in the galactic K giant stars and analysis shows that this results from much higher microturbulent velocities, 3.5-4.5 km $s^{-1}$ in the Cloud red supergiants compared to 3.5-4.5 km $s^{-1}$ for the galactic giants. The most interesting observation, however, concerned the abundances derived for different assumed stellar temperatures. The analysis was carried out using lines from the red (590 nm - 700 nm) which meant that most of the Ti and V lines were low excitation lines while the Fe lines had a much higher excitation. This mostly explains the differences in the element abundance ratios for different temperatures seen in Figure 2.

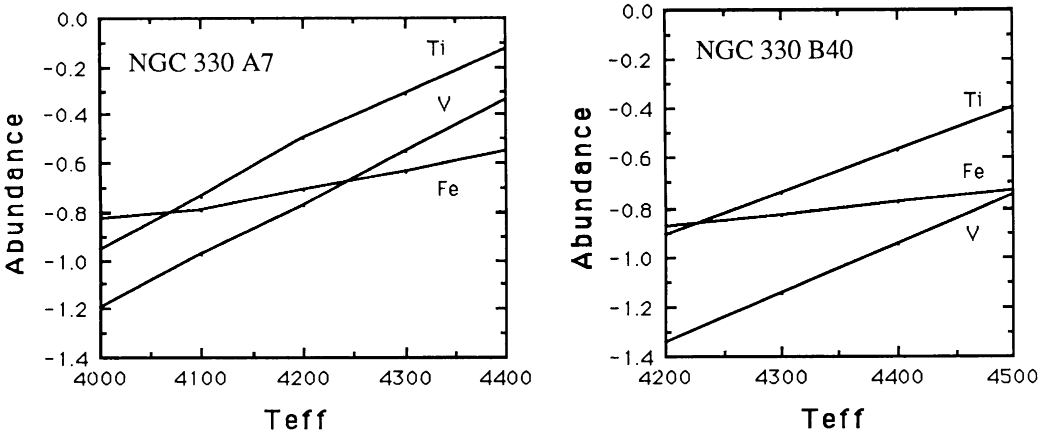


**Figure 2.** The abundances (log $Z/Z_0$) derived for different adopted effective temperatures.

The Fe abundance shows little sensitivity to temperature, whereas the Ti and V abundance is very sensitive. From the comparisons discussed above, we adopted $T_{eff}$ = 4400 and 4200K for B40 and A7 respectively, given that $T_{eff}$ = 4300K for Arcturus, and it is significant that for these temperatures the element ratios Ti/Fe, V/Fe are close to solar, and the metallicity of the NGC 300 red supergiants is close to that of the field F and G giants. If the IR colour-temperature calibration for galactic giants had been used, temperatures more than 200K cooler would have been adopted. This would have made the abundances of Fe, Ti and V smaller by about 0.1, 0.4 and 0.4 dex respectively. Such differences are evident in the analysis for A7 by Spite *et al.* (1986).

The fine-analysis of a B star in NGC 330 by Reitermann *et al.* (1990) also found a low metallicity similar to that of Spite *et al.* (1986). We have done a preliminary analysis of two similar B stars in NGC 330 and find that we can also derive higher abundances for these if we adopt a higher temperature for the Cloud B stars in comparison to galactic stars with the same U-B colours. At temperatures of about 23000K the metal abundances are quite insensitive to the temperature, so that, if such stars could be selected, their analysis would yield very reliable abundances.

It is very important to establish whether or not young cluster stars in the clouds do have much lower metallicities than the young field stars. To ensure that the result does not arise from systematic differences between the atmospheres of the Cloud stars and the galactic comparison stars, which have very different luminosities and abundances, Magellanic Cloud B giant stars and K supergiant stars in the field should be similarly analysed. If the analyses are correct, the field B and K stars will have the same abundance as the F and G supergiants. I think it likely that such analyses will show some systematic differences and I believe that the field and the clusters do have the same mean abundances. It is, therefore, also important to look carefully at the model atmosphere structures and fluxes and re-examine the question of the reddening of the Clouds.

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