THE NATURE OF THE CARBON STARS IN THE GALACTIC BULGE

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ABSTRACT. JHK photometry of 33 carbon stars we found in the direction of the galactic bulge shows that they most likely belong to the bulge population and that they are intrinsically faint, metal rich objects. The conventional mixing mechanism is excluded in their case and thus their formation is still a mystery.

Low dispersion spectroscopy provided by the Grens and Grism devices attached to the prime focus large field correctors of the Canada-France-Hawaii Telescope (CFHT) and European Southern Observatory (ESO) 3.6 m telescope, respectively, led us to detect through their C_2 Swan bands - at 5165 Å and occasionally 4737 Å - a substantial number of new carbon stars in the SMC and in dwarf spheroidal galaxies (see Azzopardi, 1987 and references herein). Furthermore at the CFHT, we discovered 33 carbon star candidates in 8 of the 9 bulge fields that we have surveyed - each 55 arcmin square - including the well known transparency windows NGC 6522, Sagittarius I and II (Baade, 1963) and the Van den Bergh-Herbst (1974) window. The success of this survey is mainly due to the low dispersion used (2000 Å mm^{-1}) and to the limited spectral range (4350 - 5300 Å) we have selected by combining a Schott GG 435 filter and the IIIa-J emulsion cut-off. The resulting spectra are rather short; thus the number of overlaps is kept rather low, even on deep exposures of those very crowded fields. All candidates were subsequently confirmed by higher-resolution spectroscopy at ESO and Las Companas Observatory (Azzopardi, Lequeux, Rebeirot, 1985; Rich, Azzopardi, Lequeux, Rebeirot, 1987).

The discovery of these rare and faint carbon stars was unexpected since the bulge population is usually assumed to be very old. In order to obtain M_{bol} and T_{eff}, infrared photometry of all 33 carbon stars was secured at the Cassegrain focus of the ESO 3.6 m telescope in the period 22-25 June 1987.

An InSb detector was used with a 7.5 arcsec circular aperture and secondary-mirror chopping and nodding techniques with variable throw amplitude and position angle. Variations in JHK magnitudes amounting in a few cases to 0.2 mag are present between observations made on different nights with different settings, while errors on the colors are slightly

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smaller. This is most likely due to the extreme crowding of the galactic bulge fields. Furthermore, similar observations made by M. Rich with the 4-m telescope at Cerro Tololo Inter-American Observatory show, in general, good agreement with the ESO measurements.

Since interstellar extinction in the direction of the bulge is not negligible in the near-infrared we are restricted here to discuss those stars located in areas for which a value for extinction has been published: the Baade window around NGC 6522 (E_{B-V} = 0.49, average of several concordant determinations), the Van den Bergh and Herbst (1974) window (E_{B-V} = 0.25) and the field around NGC 6558 (E_{B-V} = 0.41, Zinn, 1980). Figure 1 displays a $(J-K)_o/K_o$ color-magnitude diagram for

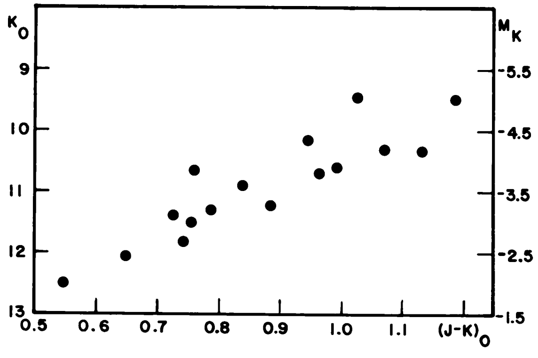

Figure 1. $(J-K)_o/K_o$ color-magnitude diagram for 16 carbon stars in the galactic bulge with known interstellar extinction.

the 16 carbon stars for which mean extinction corrections are possible. They form a well-defined sequence indicating that they must all lie approximately at the same distance and belong to the bulge. Assuming a distance of 8 kpc for the galactic center and the bulge, absolute K magnitudes show that the faintest stars are indeed very weak. A log T_{eff}/M_{bol} diagram for the same stars is presented in Fig. 2. Following Aaronson and Mould (1985), bolometric corrections have been obtained from $(J-K)_o$ using Fig. 2 of Frogel et al. (1980), while T_{eff} is taken from Table 4 of Aaronson and Mould (1985). For comparison, we have plotted the positions of M giants in the Baade window with $M_{bol} > -3$ from Table 1 of Frogel and Whitford (1987), and of red giants in the metal-rich clusters NGC 5927 ([Fe/H] = -0.16) and NGC 6553 ([Fe/H] = +0.04) according to Frogel et al. (1983) and Aaronson and Mould (1985). We also indicate the location of the red giant branch for three globular clusters with various metallicities: M92 ([Fe/H] = -2.19), M13 ([Fe/H] = -1.73) and 47 Tuc ([Fe/H] = -0.64). Metallicities for all clusters are from Zinn (1980). More information can be found in the paper by Azzopardi, Lequeux and Rebeirot (1988). Two main conclusions arise from this HR diagram:

i) The bulge carbon stars are of very low luminosity, down to $M_{bol} \simeq 0$.

ii) They are cooler on the average than all the comparison stars, except part of the bulge M giants - to the extent that their M_{bol} and T_{eff} are well determined - indicating they are metal-rich and at least some of them are probably super metal-rich as suggested by the strength of the NaD lines.

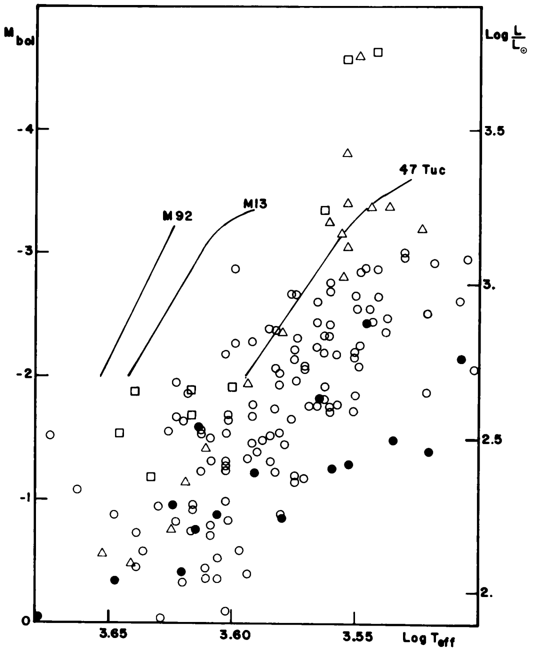

Figure 2. Log T_{eff}/M_{bol} diagram for the same carbon stars displayed in Fig. 1 (full dots). For comparison we show the positions of M giants in Baade's window (open circles), and of red giants in the clusters NGC 5927 (Δ) and NGC 6553 (□). Also indicated are the locations of the red giant branches of three globular clusters.

The conventional mechanism for carbon star formation, dredge-up of carbon during thermal pulses on the asymptotic giant branch (Iben and Renzini, 1983; Aaronson and Mould, 1985) cannot account for these objects. Their ^{12}C and ^{13}C enrichment may come from mass transfer in a binary system, but also is possibly due to another process mixing at the helium flash or the lower asymptotic giant branch (Lloyd Evans, 1985).

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