M GIANTS AT TWO LATITUDES IN THE NUCLEAR BULGE OF THE GALAXY

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I. Introduction

We are engaged in a long term study of the stellar component in the nuclear bulge of the Galaxy. Regions of low obscuration at different galactic latitudes above the galactic nucleus are surveyed for M giants with a transmission grating and thin prism at the prime focus of the CTIO 4-m reflector. Photographic and infrared photometry are obtained for samples of the stars found. Spectroscopic observations are used to investigate band strengths and radial velocities.

Work on Baade's Window (BW; Baade 1963) around NGC 6522 (latitude $-3\overset{\circ}{.}9$, 0.6 kpc below the plane) is essentially complete. Infrared photometry has been obtained for a sample 229 M giants (Blanco and McCarthy 1983; Frogel, Whitford, and Blanco 1983, hereafter FWB). Initial results have been reported by Whitford and Blanco (1979), Frogel (1981), and Frogel and Whitford (1982). Whitford and Rich (1983) have discussed the metallicities of the K giants in this window and have shown that most are super-metal-rich (SMR) with a mean $[Fe/H] = 0.3$. The spectroscopic survey of the van den Bergh and Herbst window (vHW, 1974) at $-8°$ (1.3 kpc below the plane) is nearly complete for the M5-9 giants and infrared photometry has been obtained for 49 of them.

Objectives of the program include a study of the stellar distribution, content, and metallicity in the bulge, application of these results to the construction of the population models of other galaxies (Whitford 1977), and a comparison with evolutionary models for giants.

II. The Color-Magnitude Diagram

Figure 1 shows that both windows have a significant number of stars with luminosities greater than the top of the giant branch of the metal rich cluster 47 Tuc. Because of their luminosity, they must be asymptotic giant branch stars. An important question is whether they are old (>10 Gyr), but luminous because of their high metallicity and slow evolutionary rate as suggested by Frogel and Whitford (1982),

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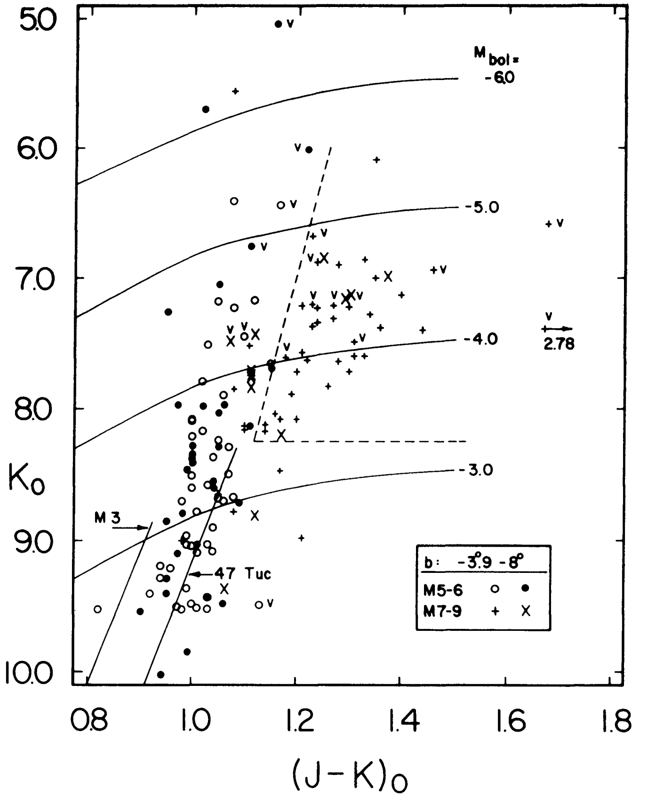
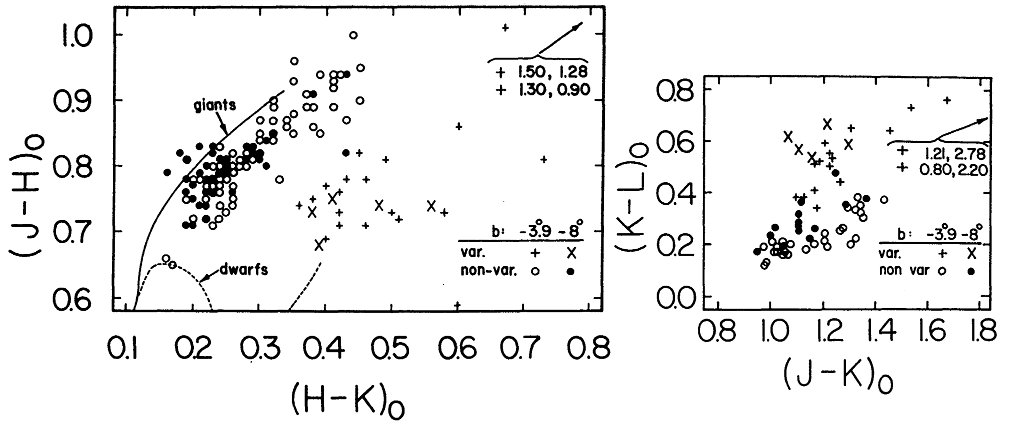


Figure 1. Photometry of an unbiased sample of M5-9 stars in two Galactic bulge windows. Variables in this sample are indicated with a v. The wedge-shaped region (dashed line) is discussed in the text.

or whether they are relatively young and massive as argued by Iben and Renzini (1983) and as Wood and Bessell (1983) suggest for the red variables in BW. Mould's (1983) kinematic data support the former interpretation.

Stars in each of the two windows are divided into two groups based on the survey spectra - M5-6 and M7-9. The relative numbers, median magnitudes, and CO and H_2O indices of stars in each of the two groups in the two windows are quite similar. Only the J-K colors of the M7-9 giants differ (cf. Fig. 1). Consider the stars more luminous than the top of the 47 Tuc giant branch. The wedge shaped region to the right contains only M7-9 stars whereas to the left stars of all spectral types are found. For the complete spectroscopic samples the ratio (vHW/BW) of stars in the wedge shaped region is 0.09 whereas it is 0.21 for the bluer giants to the left.

Lloyd Evans (1976) search BW for red variables. There are 17 in our surveyed area. Plaut's (1971) list of variables includes 6 Miras and SRas in the vHW area we surveyed. Thus the ratio of numbers of variables, vHW/BW, is 0.35.



Figures 2 and 3. Samples of M5-9 giants in two Galactic bulge windows. All variable stars observed in both windows are shown.

If the spheroidal stellar component of the Galaxy has a surface brightness which falls off like $R^{-1/4}$ and a characteristic length of 2-3 kpc, the ratio of projected stellar densities at central distances of 1.3 and 0.6 kpc is 1/3. Whereas the variables and possibly the bluer bright giants have such a distribution, the giants in the wedge shaped area of Fig. 1 are decreasing in numbers too rapidly to be in this distribution. These red stars may represent a distinct, much more condensed spheroidal component with a metallicity higher than that of the remainder or they could be the tail end of a single distribution with a steep metallicity gradient. They could also be the very central part of an exponential disk component with a scale height of not more than a few hundred parsecs. Van den Bergh and Herbst (1974) have in fact concluded that their window is somewhat less metal rich than BW.

III. JHKL Colors and the Variables

Essentially all of the BW giants lie to the right of the mean line for solar neighborhood giants in Figure 2. Globular cluster giants, on the other hand, almost all lie to the left of this line (Frogel, Persson, and Cohen 1983, Fig. 3). Frogel and Whitford (1982) suggested that this displacement of the BW giants could arise from blanketing effects on J-H and H-K colors due to their being SMR since they must have evolved from the SMR K giants found by Whitford and Rich (1983).

The variables are distinctly separated from the non-variables in Figs. 2 and 3 in each of the two windows. In Fig. 3, the distributions of the two windows are shifted in J-K as expected from Fig. 1. Glass and Feast's (1982) data are consistent with the location of the variables in the figures. The separation of the variables which lie below and to the right of the non-variables in Fig. 2 can be accounted for by the effects of stellar H_2O absorption in the JHK bandpasses (Frogel,

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Persson and Cohen 1983). For K-L the separation at constant J-K is due more to the presence of circumstellar emission from hot (800-1200 K) dust rather than from H_2O effects (FWB). The sequence of variables extending towards the reddest colors in both Figures can be accounted for by superimposing emission from hot dust on normal photospheric radiation (FWB). This sequence is quite close to that defined by solar neighborhood Miras with OH emission and circumstellar shells (Hyland, et al. 1972; Wilson et al. 1972). The 10μm emission from 11 of the BW variables (FWB) is what would be predicted from the K-L colors based on similar observations of the local Miras. The effects of hot dust and H_2O absorption make temperature estimates for the variables based on near infrared colors unreliable (cf. Wood and Bessell 1983).

It is not clear at this time whether the presence in BW of very red variables and their absence in vHM is due to the smaller numbers of stars observed in vHM or if it is related to the presence of the very red M7-9 stars in BW.

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DISCUSSION

Wing: Would you comment on the possibility of picking up some foreground stars - perhaps from the 3 kpc arm - in your fields? They might help account for the brightest stars, especially the ones that are not very red.

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Frogel: I have not checked this quantitatively yet, but Arp's analysis and Blanco's statistics indicate that the percentage of field stars will be quite low.

Richer: Is there any hope of seeing the turn-off in the high latitude field?

Frogel: It will be much easier there than in the -4° field because the star density is lower by a factor of 3.

Renzini: Do you know whether there is any heavy element abundance determination for Sgr A (or any other cloud in the galactic nucleus), and if so, how do they compare with the stellar abundances of Rich and Withford?

Frogel: Nothing has been done optically because of the obscuration. Some radio recombination line work may have been done but I don't recall any results.

McCarthy: 1) In a Grism survey similar to those mentioned by Frogel, Blanco, Meier, de Graeve and I have found in a region even closer to the direction of the galactic center a very large number of late-type M stars: more than 750 stars in an area of 0.12 square degrees. We have not detected any carbon stars. This region is one of the windows cited originally as clear by Walter Baade; it was studied for variables by Oosterhoff and is called Sagittarius I. We have discovered the spectra and determined positions for the stars; no photometry has been carried out.
2) I wish to comment the excellent photometry reported here by Frogel and his co-workers at CTIO. Especially in the dusty and crowded fields toward the galactic center photographic photometry is difficult, dangerous and should be discouraged, if possible. Frogel's work is doing so much to allow Baade's windows to shed more light on us from the galactic center.