THE GALACTIC BULGE AND THE THICK DISC

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ABSTRACT. The large reported discrepancy between the scale height in the Galactic Bulge for objects such as RR Lyrae variables on the one hand and M-giants or IRAS sources on the other is primarily due to these scale heights being determined at different mean galactocentric distances. Mira variables apparently provide a Bulge-like population in the solar vicinity and show that the thick disc consists of a number of subsystems. There are M-giants in the extended solar neighbourhood, away from the Galactic plane, which seem similar to M-giants in the Bulge. Photometric and kinematic studies on some of these stars are in progress.

1. Gradients in the Bulge

Amongst questions of relevance to our understanding of the formation and evolution of our Galaxy are: (1) Can the Galactic Bulge population be divided into subpopulations of different metallicities, ages or kinematics? (2) How is the Bulge population related to other galactic populations? (3) Is there a significant 'Bulge type' population in the solar neighbour-hood? (4) If so, is this population to be identified with another galactic component (e.g. old disc, thick disc or halo)?

Evidence has been presented (e.g. Terndrup *et al.* 1990) for a radial metallicity gradient in the Bulge. Whilst such a gradient may well exist it is important to notice that it is quite modest in the region between galactic latitudes ($|b|$) of 4° and 8° where the Bulge is perhaps best seen free from contamination by either the disc or the halo (cf. also Whitelock 1991). It has sometimes been suggested that different types of object have radically different distributions in the Bulge. The evidence for this however generally depends on a comparison of estimates of scale heights which are made at different mean distances from the Galactic Centre for different types of objects. Such comparisons can be misleading unless the distributions are exponential. For instance it seems widely believed that the Bulge defined by M-giants or IRAS sources is much smaller than that defined by the distribution of optical light or the number density of RR Lyrae variables, with scale heights of ~1500pc for the latter and a few hundred parsecs for the former (see for example Harmon and Gilmore 1988). These scale heights however apply to quite different distances from the Galactic Centre as can be seem from figure 1. de Vaucouleurs and Pence (1978) note

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that their estimates of optical surface brightness are uncertain for $|b| < 15°$ so that there is no useful overlap between their measures and those of Blanco (1988) for M-giants. The distribution of RR Lyrae variables is shallow in the outer parts of the Bulge but steepens markedly between $|b| = 8°$ and $4°$ so that the difference in distribution from the M-giants is much less than would be deduced from the scale heights quoted above. The RR Lyrae data is from Oort and Plaut (1975) with completeness corrections from Wesselink (1987). Note that the RR Lyrae point at $|b| = 3°.9$ has not been corrected for completeness and is therefore a lower limit. A similar comparison of the distribution of IRAS sources (Harmon and Gilmore 1988 figure 3) with that of the RR Lyraes shows no significant differences.

The above discussion shows that our current understanding of the Bulge does not allow us to predict which components of it could form a significant population in the extended solar neighbourhood, for that we must turn to the observations.

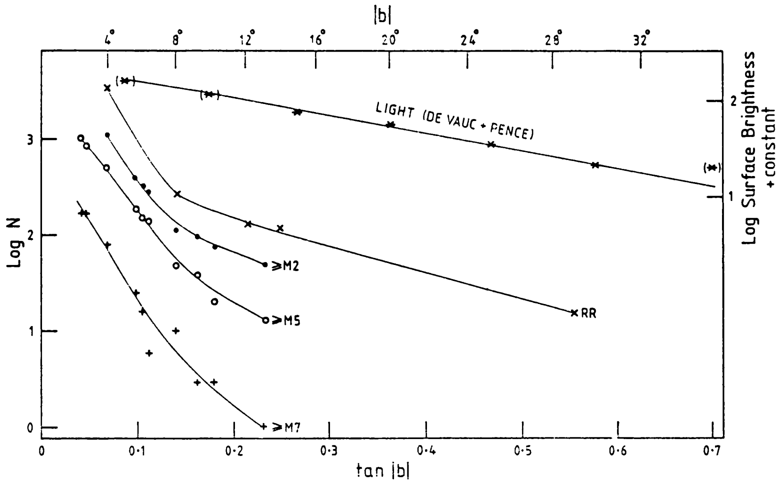

Figure 1: Distribution of surface brightness or surface number density with galactic latitude ($|b|$) for various objects. Note that log N for the RR Lyrae variables is normalized to a different unit area from the M-giants. Uncertain points are enclosed in brackets.

2. The Bulge and the Thick Disk

One of the distinctive features of the Bulge is the presence of Mira variables with a wide range of periods (Lloyd Evans 1976; Whitelock *et al.* 1991). Evidence from general galactic kinematics and from Miras in globular clusters indicates that the period range corresponds to a range in metallicities and initial masses (cf. Feast 1989 and references there). There is at present no evidence for a difference, at a given period, between Miras in the Bulge and in the solar neighbourhood. Miras can therefore be considered as tracing (part of) the local Bulge type population. Determinations of asymmetric drifts, velocity dispersions and (inferred) scale heights as a function of period show that local Miras with periods near 250 days are to be associated with a Gilmore-type thick disc population. Miras of longer period have kinematic properties near those of the old disc whilst the kinematics of shorter period stars are intermediate between the halo and thick disc (Feast 1989). These results suggest a range of disc-like systems between the halo and the old disc rather than single homogeneous thick disc. One may wish to consider these subsystems together as a 'generalized thick disc'.

Our recent work has concentrated on groups of relatively nearby M-giants which may be similar to those in the Bulge.

A characteristic of Bulge M-giants is that they are displaced in a J-H/H-K diagram from local bright M-giants (Frogel and Whitford 1987; Feast *et al.* 1990). This is plausibly a metallicity effect; the Bulge stars having [Fe/H] $\sim +0.3$. However, since the bright local M-giants are more massive and much younger than those in the Bulge the effect could be at least partly due to a difference in surface gravity (cf. Feast *et al.* 1990). A sample of local M-giants of intermediate type (generally M2 and M3) at a mean height of $\sim$ 500pc above the Galactic plane show that there are M-giants in our region of the Galaxy in the same position in the J-H/H-K diagram as Bulge stars (Feast *et al.* 1990 figure 7). This reinforces the conclusions drawn for the Mira results that there exists a 'generalized thick disc ' component which can be regarded as the local Bulge type population.

The Bulge contains a large number of late M-giants (M5 and later). The many late M-giants found by Stephenson (1986) in the extended solar neighbourhood with $|b| > 10^o$ are candidates for local representatives of this Bulge population (cf. Feast *et al.* 1990). Many of them are in the same region of the J-H/H-K diagram as Bulge stars. Adopting a visual absolute magnitude for these local stars similar to that of the late M-giants in the Bulge, Stephenson estimated a scale height (z) for his stars of $\sim$900pc. There are however some problems with both his system of magnitudes and his method of analysis and a revision is in process. We have also obtained radial velocities of 228 of Stephenson's stars and these data should allow us to compare their kinematics with those of other populations.

Studies of local Miras and M-giants away from the Galactic plane seem a promising way of investigating the more metal-rich components of the local Bulge type populations.

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